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# METHOD OF ENGINEERING FLUID DYNAMICS (EFD) CONCEPT APPLICATION ON RESEARCH OF FLOW CHARACTERICTICS OF BUTTERFLY-VALVES

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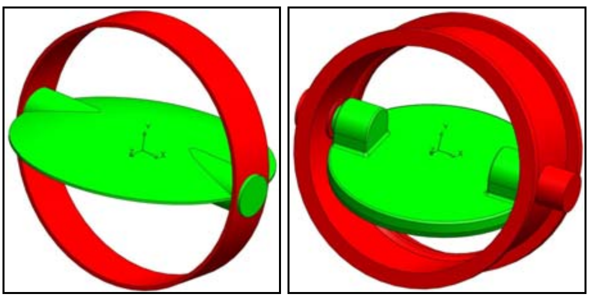
**ABSTRACT**
*For manufacturers and users of the butterfly-valves, there is a strong need for determining the flow characteristics-coefficients of these valves.*
*This paper presents the method of calculating the flow coefficients of butterfly-valves, based on the application of Engineering Fluid Dynamics (EFD) concept, which allows easier, faster and cheaper numerical simulations in comparison to other computer aided methods.*
**Keywords:** butterfly-valve, flow coefficients, Engineering Fluid Dynamics

## 1. INTRODUCTION AND OVERVIEW OF PREVIOUS RESEARCHES

There are numerous papers which treat research thematic of determining the flow characteristics-coefficients of butterfly-valves [2,3,4,5].
In this paper, first were realized numerical analyses of flow characteristics of butterfly valves with a shutoff valve-body in the form of lens (Fig. 1a), whose results were used to compare with experimental results with the same shut-off body, given in [5]. With this is done verification of possibility for application of EFD concept and the SolidWorks Flow Simulation solvers software for numerical analyses of flow in the butterfly valves. After that numerical analyses of flow in the model of real-butterfly valve with manufacturer label KDG-T were realized (3-D model is given in Figure 1b.), using the aforementioned software SolidWorks Flow Simulation.



a) b)

*Figure 1. 3D models of the analyzed butterfly-valves*
*a) model with a shutoff valve body in the form of lens,*
*b) model of real-butterfly valve with manufacturer label KDG-T*

## 2. ENGINEERING FLUID DYNAMICS (EFD) CONCEPT

Engineering Fluid Dynamics (EFD) concept presents a next generation of fluid flow and heat transfer analysis technology (since 1999). For the first time EFD concept made fluid simulation an integral part of the design process and predicts real world behavior of new products in early and all phases of the design cycle. EFD helps qualified engineers to give answers earlier, faster, cheaper and safer than any other engineering method.

With EFD, engineers have an integration of CAD system and simulation software with power and specific automatic grid generation. In simulation software the finite volume method has established itself as the method for simulating flow, heat and material transfer. The EFD programs can automatically identify both the enclosed internal flow space and the outer flow area, as well as the solid areas of different materials involved in flow and/or heat transfer. A grid of hexahedron elements is then automatically generated for the entire calculation area using RAM (Rectangular Adaptive Mesh) technology, and the grid density is automatically adjusted at geometrically and physically critical areas.

Engineers start with preliminary 3D CAD model. Changes and optimizations to the geometry based on findings from the simulation calculations can be made directly in the CAD system. In this paper the concept of EFD was applied through the application of previously mentioned software SolidWorks Flow Simulation.

## 3. FLOW CHARACTERISTICS OF BUTTERFLY-VALVES

Two important flow characteristics of butterfly valves- which are investigated in this work are **drag coefficient** and the **flow coefficient**. These values are typically obtained experimentally.

The most commonly used expression that connects the pressure drop with fluid flow through the valve is Darcy-Weisbach relation [1]:

$$\Delta H = \zeta \frac{v^2}{2g} \tag{3.1}$$

where: $\Delta H$ - loss of effort expressed in [m], $\zeta$ - dimensionless coefficient of resistance, $v$ - flow velocity of fluid [m/s] i $g$ - gravitational acceleration [m/s$^2$].

**The coefficient of resistance** can be expressed from (2.1):

$$\zeta = 2g\frac{\Delta H}{v^2} \qquad \text{or} \qquad \zeta = 2\frac{\Delta p}{\rho v^2} \tag{3.2}$$

where: $\Delta p$ -the pressure drop is expressed in [Pa] and $\rho$-fluid density [kg/m3]

**The flow coefficient** is given depending on the angle of valve opening. This size is particularly important when the butterfly-valve is used to regulate the amount of flow.

In industrial practice flow coefficient Cv is often used, given by the following expression [5]:

$$C_v = \frac{Q_{gpm}}{\sqrt{\Delta p_{ISA} / S_g}} \tag{3.3}$$

where: $Q_{gpm}$ -the flow is expressed in [gpm] , $\Delta p_{ISA}$ - pressure drop between the 2D position before the place of valve installation, and 6D behind the valve, expressed in [psi], *Sg*-Specific weight of fluid (water is 1).

However, in this expression the pressure drop includes the pressure drop due to friction. For the ratio Cv/d2 higher than 20 effect of friction can not be ignored, so the pressure drop should be calculated using the following expression:

$$\Delta p_{net} = \Delta p_{ISA} - 0{,}008986 \cdot S_g \cdot f \cdot \frac{Q^2}{d^4} \tag{3.4}$$

where: f - friction factor.

The relationship between this coefficient and drag coefficient is given by the following expression:

$$\left[\frac{C_v}{d^2}\right]^2 = \frac{890{,}6032}{\zeta} \tag{3.5}$$

Another flow coefficient that is encountered is $C_D$. The advantage of this coefficient is that it is unlike Cv dimensionless, and always has a value in the range 0-1. If the fluid velocity is known pressure drop can be calculated using the following equation [1]:

$$C_D = \frac{v}{\sqrt{2g\Delta H + v^2}} \tag{3.6}$$

## 4. NUMERICAL ANALYSIS OF BUTTERFLY-VALVES FLOW CHARACTERISTICS

### 4.1 Validation

The results of numerical simulations should be checked in terms of their quality, accuracy and reliability. This is the task of validation. It answers the question of how accurate and reliable results of simulations by direct comparison with experimental results. The process of validation, among other things, includes the repetition of calculation with a higher degree of discretization until satisfactory accuracy of obtained results is achieved. After performing numerical simulations with different resolutions of numerical mesh a setting that has generated 90 000 fluid and 50000 partial cells was adopted. In area around the shutoff valve-body mesh of higher density was generated, because there are expected largest gradients of observed quantities, such as pressure and speed.
The diagram in Figure 2 compared the values of the coefficient $C_v$ obtained by numerical calculation based on expression (3.3) with the results of experimental studies. In determining the pressure drop influence of friction in accordance with expression (3.4) is taken into account.

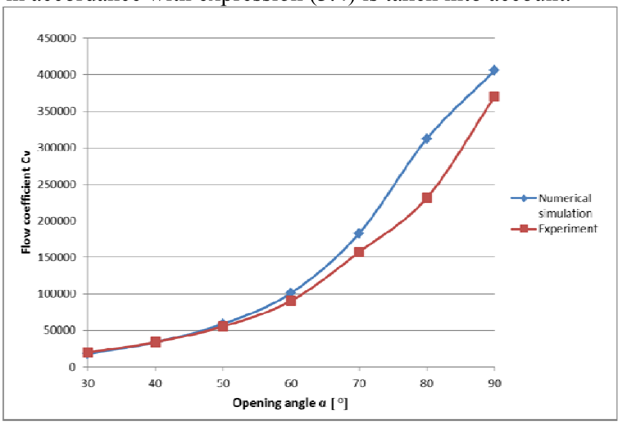
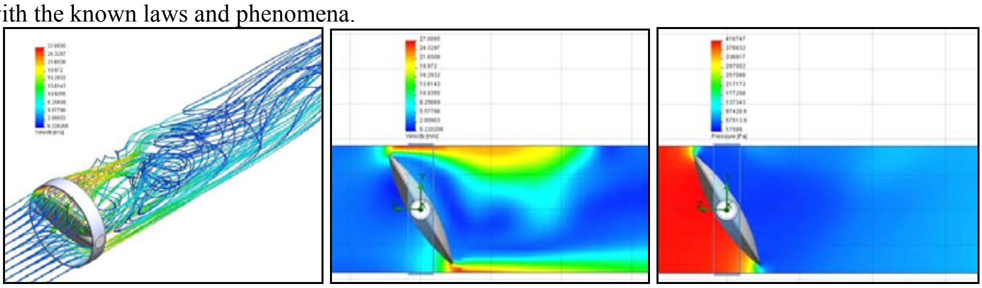



*Figure 2. The flow coefficient Cv obtained numerically and experimentally*

By analyzing the obtained results turbulence behind the shutoff valve-body was observed (Fig. 3a), which is intensified with decreasing angle of closing, as well as the pressure drop in places where there is a higher speed (Fig. 3b and 3c). Changes in these parameters are in line with expectations and with the known laws and phenomena.



*a) b) c)*

*Figure 3. The values of flow parameters for the opening angle 30 °*
*a) streamlines, b) velocity distribution, c) distribution of pressure.*

### 4.2 Numerical analysis of flow characteristics of selected butterfly-valve KDG-T

After completion of validation of the example valve body with a shutoff valve-body in the shape of the lens, an analysis and calculation of important parameters of flow for valve KDG-T (Fig. 1b) was performed. The same boundary conditions as well as a way of measuring of flow parameters were applied. Due to the symmetry of the flow observed in the previous case an additional boundary condition of symmetry was applied, and the resolution of mesh was further enhanced in order to obtain more accurate results. The final mesh for this analysis was 180 000 Fluid and 110 000 partial cell. Based on the performed numerical simulations values for the drag coefficient $\zeta$ , flow coefficient $C_v$ and $C_D$ were calculated. The diagram in Figure 4 shows the values of the coefficient $C$v.

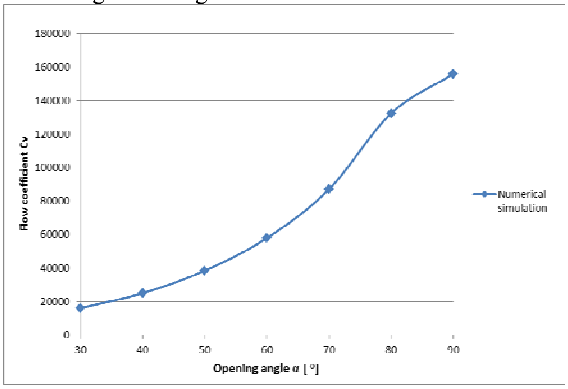
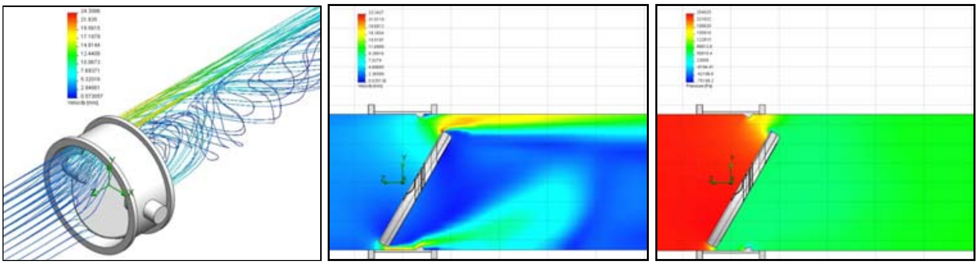



*Figure 4.  Flow coefficient $C_v$ obtained numerically*

Figure 5 shows the streamlines (5a) and the velocity distribution (5b) and pressure (5c) for butterfly-valve KDG-T.



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

*Figure5. The values of flow parameters for the opening angle 30 °*
*a) streamlines, b) velocity distribution, c) distribution of pressure*

## 5. CONCLUSIONS

The obtained results show that the use of EFD concept, based on the application of CAD technology and method of finite volume which were performed in SolidWorks Flow Simulation software, gives good results when analyzing the flow characteristics of butterfly-valve. It was confirmed that the EFD concept  allows easier, faster and cheaper numerical simulations in comparison to other computer aided methods. In future studies, process of verification and validation of the results of applying the concept of EFD should be given extra attention in order to precisely estimate the degree of matching the results of applying the said EFD concept and experimental results.

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