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ARTICLE

Investigation of Erosion Corrosion Caused by Drinking Water in the Faucet with Computational Fluid Dynamics

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ABSTRACT

In this study, the reason for erosion-corrosion of drinking or mains water in the faucet was investigated by computational fluid dynamics. Pipes used in homes, the service sector, and industry are responsible for transporting different types of fluids from one place to another. Considering the faucet design, the SolidWorks program was used for 3D studies. In-faucet flow analyses were performed using Ansys Fluent, a computational fluid dynamics program based on the finite volume method. In the analyses, lime particles were chosen. At the end of the analysis, the amount of erosion in the faucet was obtained.

Keywords: Faucet; Erosion corrosion; CFD; Simulation

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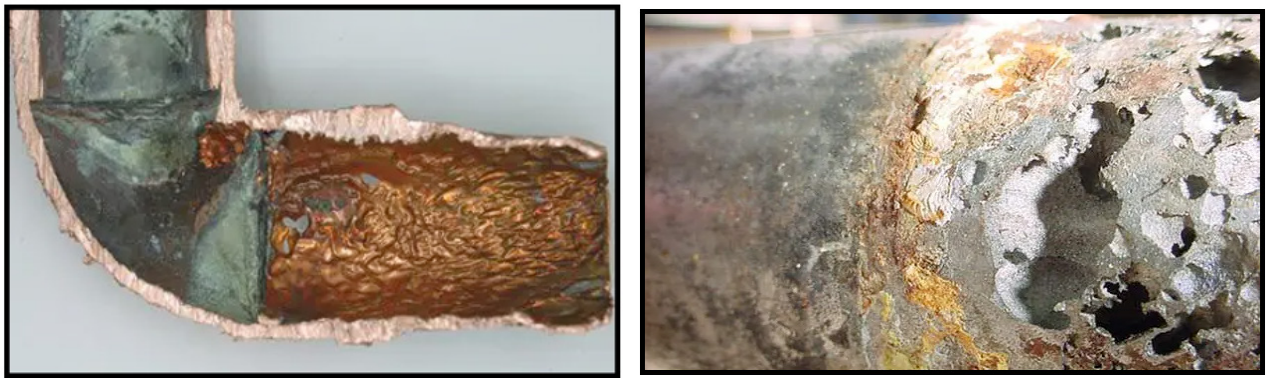
1. Introduction

Corrosion is an inevitable process that takes place due to the interaction of metals and alloys with their environments. This is an interfacial reaction that occurs between the metal and the environmental components. Metal takes a high-energy state in the production of metallic structures. It has a strong tendency to return to its low-energy state. This process of returning to its natural state is called corrosion. The corrosion may occur locally in the form of a pit or crack or as an overall deterioration that extends over a large area. The corrosion results are much more important than a simple material loss, as the safe and efficient operation of the structures is in question. Pipes, tanks, metal parts of machinery, ships, bridges, etc. Economic losses due to material loss in structures are important corrosion problems [1,2]. When combined with mechanical factors that cause wear, impact, and pitting, the economic losses caused by corrosion reach very high values [3,4]. General corrosion, galvanic corrosion, crevice corrosion, pitting corrosion, intergranular corrosion, stress corrosion and erosion corrosion are among the most important corrosion types (**Figure 1**).

In such applications, different solution methods can be found by predicting the corrosion damage to be caused by the fluid by using computer-aided simulation tools. There are several studies in the literature on the subject. Mansouri et al. [6] studied the turbulence model around the wall and the erosion of the reason for small particles. Hassan-Beck et al. [7] investigated the effect of flow on erosion in nozzle outlets. Doroshenko et al. [8] researched the flow analyzes to get a physical image of the acting of condensed droplets. Pat et al. [9] studied the mechanism of solid particle erosion. Kumar et al. [10] investigated the erosion wear behavior of the pipeline due to solid-liquid suspension Mohyaldinn et al. [11], the Salama model and the Direct Impact Model (DIM) model, have developed a computational code for predicting the erosion of particles (sand) in pipe components. These two models are compared to results from the CFD Fluent commercial software. In this study, erosion corrosion the reason for drinking water in the faucet was investigated by CFD. As a result, the amount of erosion in the faucet was calculated using Fluent modüle of Ansys Workbech. The erosion values that occur in the pipes can be yearly calculated as millimeters by inputting the erosion rate values obtained by using Ansys Fluent software.

2. Material and method

SolidWorks program was used for the 3D modelling process of the faucet (**Figure 2**). The CFD analyses were completed using the Ansys Fluent module. The properties of the liquid (water) to be used as a fluid in flow analysis were entered into the program. Lime ($CaCO_3$) was chosen for the particle to be carried by the liquid. The properties of the liquid and the particle are given in **Table 1**. The faucet was manufactured from steel.



a) **b)**

Figure 1. Corrosion types, a) Corrosion-erosion on stainless stell tube, b) Corrosion – erosion process on stainless steel [5].

Figure 2. 3D model of faucet.

Table 1. The properties of the H_2O and $CaCO_3$.

Fluid (H_2O)	Values
Density (kg·m^{-3}) of H_2O	998.2
Viscosity (kg·ms^{-1}) of H_2O	0.001003
Velocity Magnitude (m·sn^{-1}) of H_2O	0.5
Initial Gauge Pressure (MPa)	78000
Particule ($CaCO_3$)	
Diameter (mm) of $CaCO_3$	0.015
Diameter Distribution of $CaCO_3$	Uniform
Total Flow Rate (mg) of $CaCO_3$	60
Drag Law	Spherical

2.1 Loading and boundary conditions

Figure 3 shows inlet and outlet surfaces on the geometric models. The element type was chosen as a triangle for mesh operation. After mesh processing, the finite volume model has 16392 nodes and 39879 elements. The meshing process is shown in **Figure 4**. In all of the flow analyses, the initial velocity was chosen as 0.5 m/sec from the inlet surface of the pipe. Equation (1) gives the erosion model in ANSYS Fluent.

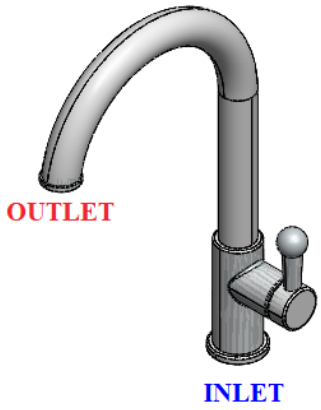


Figure 3. Inlet and outlet surfaces.

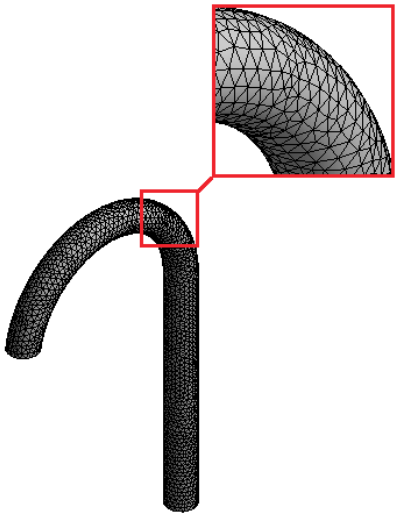


Figure 4. The mesh of finite element model.

$$ER = \sum_{p=1}^{N_{particles}} \frac{\dot{m}_p C(d_p) f(\alpha) {v_p}^n}{A_{face}} \quad (1)$$

where, $\dot{m}_p$ is the mass flow rate, $f(\alpha)$ is the impact angle, $C(d_p)$ is the function of particle diameter, v_p is the impact velocity of the particle, n is the speed exponential, A_{face} is the area of the cell face at the wall [12].

3. Results and discussion

After the required processes, the analyzes were solved. As a result of the analysis, the erosion rate was calculated as 6.15E-10 kg/m^2·sec (**Figure 5**). Based on experience, it is known that the mains water used in the houses forms corrosion due to erosion in such transport elements after a certain period. However, with the development of computer-aided solution tools in recent years, such situations can be calculated by using finite element analysis (FEA) or computational fluid Dynamics (CFD) solution methods, by correctly defining geometry, material models, and boundary conditions in the computer environment. Thus, such problems that require time and high cost can be solved in a shorter time. Ada ve Kadir [13] investigated the effect of design effect on erosion-corrosion in their study. In their analysis with CFD, they calculated that erosion-corrosion occurs less in elbow pipes with a round cross-section. The erosion-corrosion occurring in the nozzle

the abrasive water jet-cutting process was simulated in the computer environment by Ada et al. [14] (**Figure 6**).

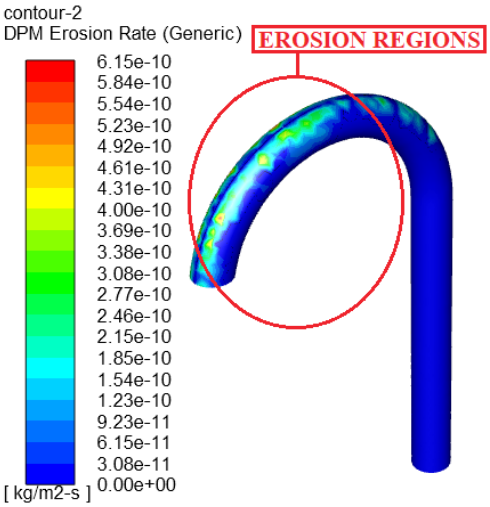


Figure 5. DPM Erosion rate.

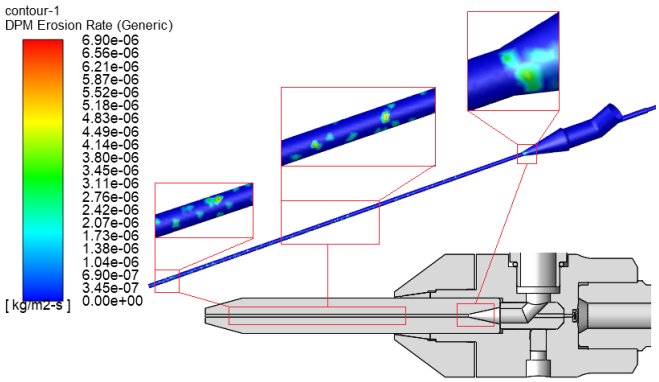


Figure 6. Erosion rate in the nozzle [14].

A software was developed using Visual Basic by Ada et al. [14] according to Equation (2). The erosion values that occur in the pipes can be yearly calculated as millimeters by inputting the erosion rate values obtained by using Ansys Fluent software (**Figure 7**). Thus, the errors caused by the calculation would be eliminated. Here ρ is density. Material density is an effective parameter for calculating the amount of erosion. This value was converted as 2.48e-3 (0,00248) mm yearly.

$$EM = \frac{ER\left(\frac{kg}{m^2 s}\right)}{\rho\left(\frac{kg}{m^3}\right)} \times 1000\left(\frac{mm}{m}\right) \times 3600\left(\frac{s}{hr}\right) \times 24\left(\frac{hr}{day}\right) \times 365\left(\frac{day}{year}\right) \quad (2)$$

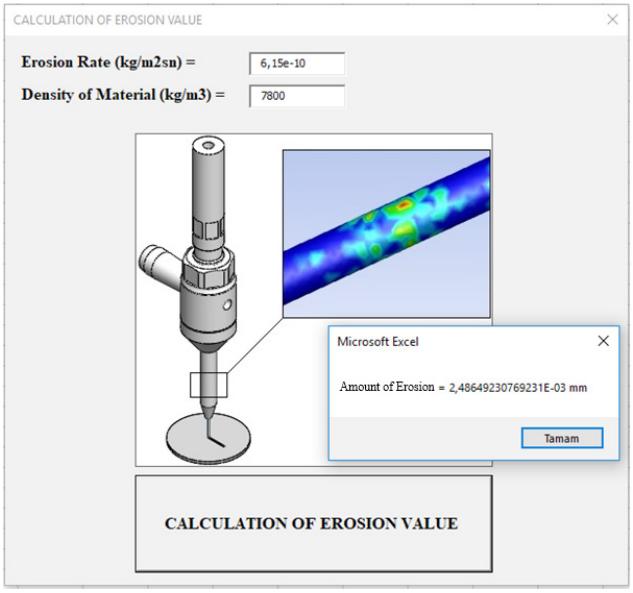


Figure 7. Calculation of yearly erosion value.

Erosion corrosion is also encountered in other types of industrial applications. Especially in cutting and drilling operations such as water jets, high fluid pressure shows that the nozzles are subject to erosion corrosion in a short time. The sectioned nozzle and the silicon casting of WC were seen in **Figure 8**.

Figure 8. The sectioned nozzle and the silicon casting of WC [15].

Corrosion does not begin in the form of general battery reactions. However, subsequent reactions form the basis of many chemical reactions. Metals dissolve from the metal surface and leave as metal ions. These dissolved ions can form solid chemical compounds. Erosion corrosion is responsible for this dissolution and chemical compound formation. These solid corrosion products are also removed by mechanical treatment. Most metals or alloys are susceptible to erosion corrosion. The protective oxide layer that forms on the surface of metallic structures such as stainless steel and aluminum is lost after erosion corrosion and the structures quickly become vulnerable to many other types of corrosion. It is resistant to corrosion due to the oxide layer on the 316 L stainless steel sample in a sulfuric acid envi-

ronment. However, when $FeSO_4$ moves in an H_2SO_4 environment containing solid particles, it corrodes rapidly. Passive film disappeared due to solid particles and metallic dissolution started rapidly [16]. As a result, erosion corrosion, like other species, is based on electrochemical mechanisms.

4. Conclusions

Mains water that we use for our daily needs, especially in our homes, can cause erosion corrosion on the faucet and other elements. FEA and CFD are important for solving engineering problems. These methods present in terms of comprising experimental and analytical results. It has been used effectively in the solution of engineering problems in the field of health in recent years, and is especially effective in reducing experimental costs.

Conflict of Interest

The authors declare that he has no conflict of interest.

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