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WATER FLOW SIMULATION THROUGH THE DRAFT TUBE FROM A FRANCIS TURBINE

Emilia SABĂU, Mihai-Andrei DRAGOMIR, Adrian POPESCU, Brînduşa-Aniela RUSU

Abstract: *The design and shape of the draft tube are factors that directly influence energy recovery. A draft tube with an elbow shape for low heads of water flow was studied. The aim was to identify the significance of the draft tube design according to the performance of the Francis turbine. A dimensional calculation was carried out for this purpose, followed by a finite element simulation using Flow Simulation software to verify the velocity of the water flowing through the draft tube. The results of this simulation lead to the fact that the draft tube design is a factor that affect the pressure and velocity at the draft tube's inlet and outlet.*

Key words: *flow simulation, Francis turbine, draft tube, elbow, energy.*

1. INTRODUCTION

The Francis turbines are the type of turbines that are most used in medium and large head in hydroelectric plants.

The main advantage of this turbine is the fact that it changes the direction of the water flow [1]. Because the water flow is changing in the turbine this leads to different problems that can appear [2].

The turbine component that forms the downstream part of this is the draft tube. Its role is to transform the kinetic energy of the runner's water flow into static pressure [3], [4].

The draft tube is the part that connects the runner to the tail race outlet, guiding the water out of the turbine [5], [6].

Its principal function is to reduce the water flow velocity before it exits the turbine and to minimize the kinetic energy loss at the exit; this allows the draft tube to be assembled upper the tail water without losing any available head or net head.

Since, in the draft tube the energy recovery is a factor that affects turbine performance as well as turbine power output, the improvements in turbine design or the draft tube itself are of grate interest [7-9].

A Francis turbine uses materials more precisely, like 16Cr5Ni. This material can be used because it is a steel with a good weldability. The weldability is done without preheating, the steel is in fact a high-quality steel. Additive technologies can become an innovative tool in many domains, offering new possibilities, like in this area to obtain complex parts with a good resistance [10-13].

Finite Element Method (FEM) simulations were used to predict the accuracy in complex flow domains. Numerical simulations in elbow draft tube of the Francis turbines were analyses in many studies by different researchers [14-21].

In this article, we have chosen the draft tube as a bend draft tube with a conical exist diffuser, the choice of this draft tube was made instead of the straight conical draft tube.

It was chosen considering that the velocity of the water flow will decrease along the draft tube because of the bend. By reducing the velocity, the efficiency of the entire turbine will be increased compared to a straight conical draft tube, with the same velocity at the draft tube's exit and admission.

The FEM model was used to do the simulation of water flow through a bend draft tube of a Francis turbine.

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2. DRAFT TUBE DESIGN

The most common draft tube design is a bend draft tube. This one features a straight cone in the first section following the runner outlet, and then a bend part. The draft tube's straight section was designed before the bend to reduce the velocity of the water flow that came from the water before it arrived at the draft tube's bend. The straight section of the draft tube was also chosen since an elbow type draft tube leads to problems regarding the separation and cavitation. The flow begins to accelerate towards the output at the curve of the draft tube; this acceleration is undertaken to avoid separation.

The elbow draft tube design is such that energy loss is minimized by changing the direction of the water flow from vertical to horizontal. Some designs of this type of turbine are also made with the aim of recovering part of the kinetic energy (the recovery takes place at the level of the original cone, but also at the elbow); the third part of the tube can also be designed to recover kinetic energy, but with a lower recovery value than the initial part of the tube because the velocity at the admission section of the diffuser is different from that of the initial part of the tube, the part of the diffuser being considerably reduced.

Draft tube designs can be of two types, straight conical draft tube and draft tube with elbow. The direction of the water that goes through the draft tube will also be influenced by the elbow structure. When considering the waterfall head, which is 69 [m], the elbow conical draft tube is used instead of the straight conical draft tube. The normal recommendation for this type of waterfall is to use a straight conical draft tube, as the velocity of the water flow is constant from when the water enters the draft tube until it exits the pipe. Taking this into consideration, we designed an elbow draft tube with a conical exit diffuser to achieve smaller velocity at the exit of the draft tube. The lower speed of the draft tube exit leads to a better efficiency of the entire turbine.

The key to finding problems in draft tubes is to make parametrization of an elbow draft tube with a conical exit diffuser.

We choose to divide the draft tube in three parts: the suction head, elbow, and the exit diffuser, that are presented in Fig. 1.

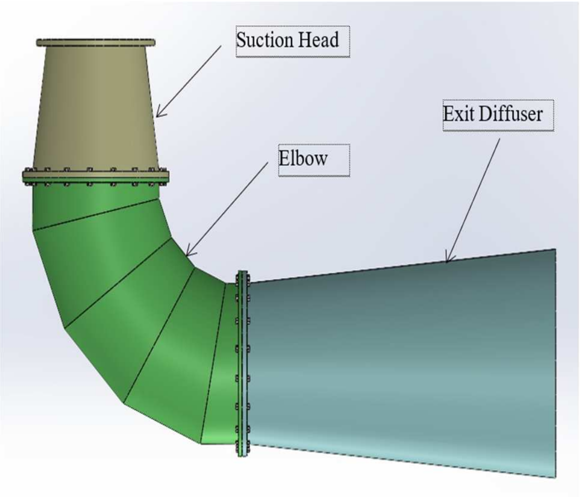


Fig. 1. The components of the draft tube

The elbow that was projected in this paper was manufactured from five tubes that were cut at different angles and then welded together. This manufacturing process of the elbow was done to avoid the stress tensions that can appear in the tube bending at 90°.

3. DRAFT TUBE PARAMETRIZATION

To parameterize the draft tube, calculations were made to obtain the required dimensions for it.

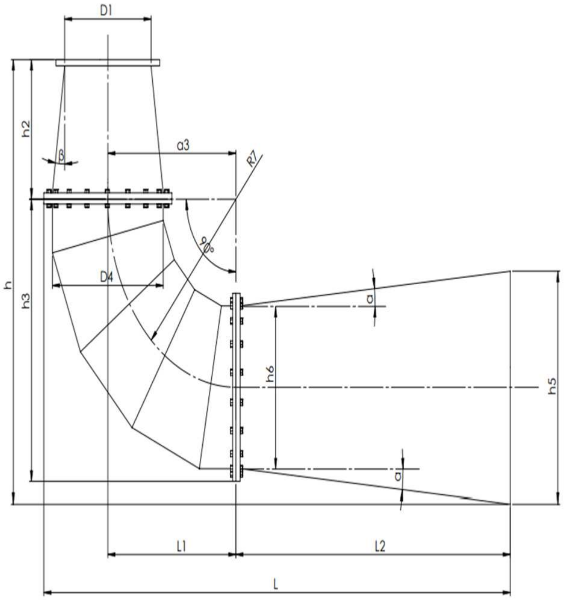


Fig. 2. Parametrization of the CAD model

The parameter D from the draft tube is equal to the admission diameter of the runner D_1, resulting in the fact that $D=Ds=0.8$ [m].

If $h_k/D=1$ then D_4 will be calculated according to the following formula:

$$D_4 = \frac{D_3 + (h - h_1)2\,tg\,\beta}{1 + 2\,tg\,\beta} \tag{1}$$

where: h - height of the tube.

If $h_k/D\neq 1$ then D_4 will be calculated with the following formula:

$$D4 = 2tg\beta(h - h_k - h_1)D3 \tag{2}$$

The thickness of the draft tube for heads which are smaller than 200 meters is between 10 and 20 [mm], while the components that are part of the draft tube are assembled by flange or by welding. For this article, the draft tube thickness was 15 [mm].

4. FLOW SIMULATION IN THE ELBOW DRAFT TUBE

The CAD model of the draft tube was created in SolidWorks program using the calculated parameters. After that, it was implemented in Flow Simulation, a SolidWorks package, to check the water flowing velocity through the draft tube.

The velocity distribution is shown in Fig. 3 and Fig. 4, illustrating that the fluctuation of the water flow caused by the direction of the runner entering the section head is redirected through the elbow. In these images, we can see that the pressure of the flow decreases due to the variation that produces flow separation in the part where the elbow is, the separation is done on the walls of the elbow. The disadvantage of this decrease in pressure of the water is the fact that after the elbow, a flow recirculation zone is produced (it can be observed in Fig. 5), this region is located between the exit of the elbow and the outlet of the exist diffuser. This flow recirculation zone is because between the suction head and the exit diffuser exists this abrupt change of the section which is represented by the elbow.

Although the velocity decreases at the outer wall of the elbow, as shown in Fig. 3 and Fig. 4, and the pressure will increase at the outer wall of the elbow; as seen in Fig. 6 and Fig. 7.

The uneven velocity distribution observed in Fig. 4(a) is due to the swirl changing the direction of water flow on one side of the elbow, causing an uneven distribution at the exit diffuser.

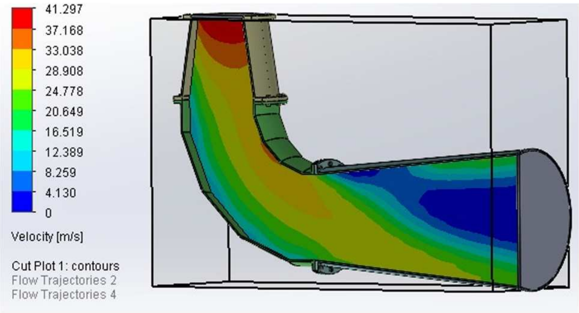
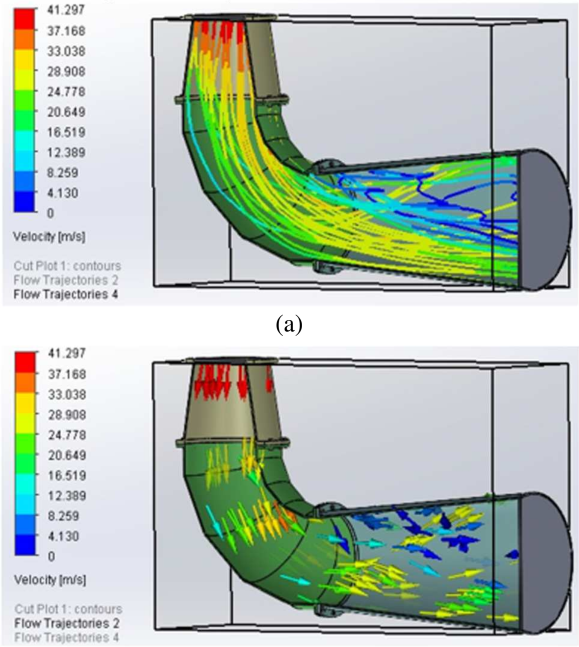


Fig. 3. Velocity contours of the draft tube



(a)

(b)

Fig. 4. (a) Streamlines velocity of the draft tube (b) The arrows flow velocity of the draft tube

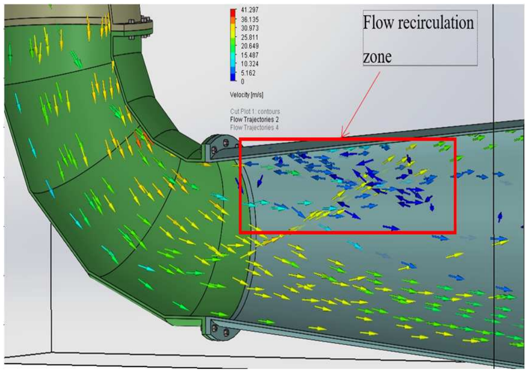


Fig. 5. The Flow recirculation zone of the draft tube

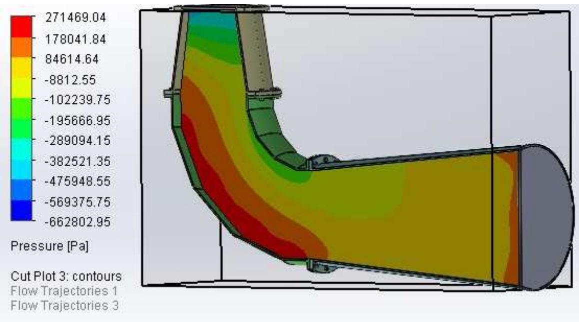


Fig. 6. *Pressure contour of the draft tube*

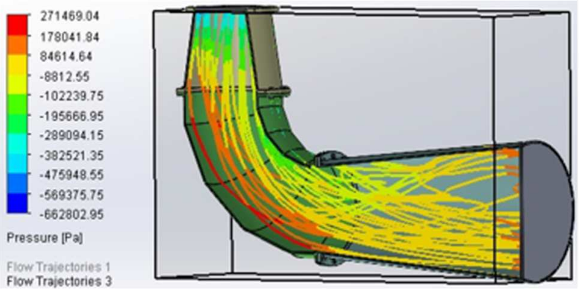


Fig. 7. (*a*) *Streamline pressure of the draft tubes*

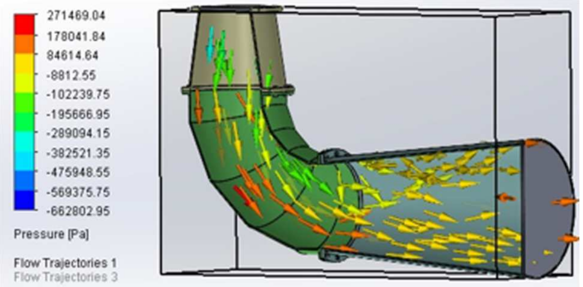


Fig. 7. (*b*) *The arrows flow pressure of the draft tube*

The results obtained from simulation show that the design of the draft tube influences the pressure and velocity at the draft tube's admission and outflow.

The draft tube is an important component, the simulation of the CAD model shows how vital in performance of the Francis turbine is this part.

5. CONCLUSIONS

In this article was presented the importance of draft tube design on a Francis turbine.

The parametrization was carried out by calculating a part of the runner parameters to obtain the draft tube parameters.

A CAD model was made in SolidWorks with the parameters obtained previously from the calculation. Based on the water flow simulation analysis into the draft tube, it was determined that the design has a vital importance to the performance of the turbine.

We remarked the fact that after the flow passes through the draft tube’s elbow, the velocity of the flow decreases, and the pressure increase near the outside wall of the elbow. Despite the velocity decreases, a flow recirculation zone forms in the exit diffuser.

It has been observed that the design and geometry of this draft tube leads to the velocity at the elbow section to be particularly constant, a slight decrease in the level of the area located in front of the diffuser is observed.

The area of the elbow presents an influence upon the flow efficiency of the draft tube, as observed by the fact that, on the one hand the velocity decreases, on the other hand the pressure increases. This difference between velocity and pressure is reflected in the efficiency and loss of the entire turbine.

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SIMULAREA CURGERII APEI PRIN TUBUL DE ASPIRATIE DINTR-O TURBINA FRANCIS

REZUMAT: Proiectarea şi modelarea tubului de aspiraţie sunt factori care influenţează direct recuperarea energiei. Lucrarea analizează un tub de aspiratie cu cot pentru debite joase de apă. Scopul a fost de a identifica importanța proiectării tubului de aspiraţie în funcţie de performanța turbinei Francis. În acest scop s-au facut calcule de dimensionare, iar cu ajutorul programului Flow Simulation, s-a realizat o simulare cu elemnte finite pentru a verifica viteza parcurgerii apei prin tubul de aspirație. Concluzia acestei simulări a condus la faptul că proiectarea tubului de aspiraţie este un factor care afectează viteza şi presiunea la intrarea şi ieşirea din tub.

Emilia SABĂU, Associate Professor Ph.D. Eng, Technical University of Cluj-Napoca, Manufacturing Engineering Department, Emilia.Sabau@tcm.utcluj.ro, B-dul Muncii no. 103-105, Cluj-Napoca;

Mihai-Andrei DRAGOMIR, Eng., Technical University of Cluj-Napoca, Manufacturing Engineering Department, d.andrei6@yahoo.com, B-dul Muncii no. 103-105, Cluj-Napoca;

Adrian POPESCU, Senior Lecturer PhD. Eng., Technical University of Cluj-Napoca, Manufacturing Engineering Department, Adrian.Popescu@tcm.utcluj.ro, B-dul Muncii no. 103-105, Cluj-Napoca;

Brînduşa-Aniela RUSU, Lecturer PhD., University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, Forestry Department, aniela_brindusa@yahoo.com, Calea Manaştur no. 3-5, Cluj-Napoca.