Francis Turbine Analysis & Performance Prediction

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The energy matrix in Costa Rica is dominated by the hydraulic energy. The Costa Rican Institute for Electricity (ICE by its acronym in Spanish) has enough experience in the building and operation of hydraulic projects, as well in the maintenance of turbines. The performance characterization of the repaired turbines are done experimentally, but in the ICE there is a lack of knowledge on the theoretical and computational areas. This problem will try to be solved through this research in which the computational characterization of the hydraulic performance of a repaired turbine will be done.

Keywords: Francis Turbine, Performance Prediction, CFD.

I. Introduction

Nowadays the computer fluid dynamics (CFD) is the novel technique in the flow simulation in engineering and science.

In literature, there are many publications in the computational analysis of hydraulic turbines, for example: the hydraulic induced stress analysis in a turbine by Saeed, Galybin and Popov [1], the transient analysis of the interaction between the stator and the Francis turbine by Anup, Bola, and Young [2] or the Large Eddy Scale simulation in the turbulent flow by Zang ,Wang and Guo[3].

There are no registers in Costa Rica for this kind of CFD analysis, and there are not many references in the literature with a turbine of high power scale (>10 MW).

II. ROTOR SCANNING & CAD MODEL

There were some turbines under maintenance in the ICE during the realization of the project. One of the turbines belongs to the Manuel Pablo Dengo hydraulic Project (also known as Corobicí Project) was selected for the analysis. Nowadays, it is the biggest operational project in Costa Rica, with three Francis turbines of 60 MW of power. The table 1 shows some basic data of the Corobicí Project.

TABLE I
COROBICI BASIC PARAMETERS

Parameter	Value and units
Height (H)	198 m
Discharge (Q)	32.5 m³/s
Power (P)	58600 kW
Efficiency (η)	92.87 %
Rotational speed	360 RPM

The selected rotor was scanned with FARO Edge technology, generating a point cloud. This information was analyzed and processed with CAD tools, in order to produce a smooth surface of the passages, blades, and other parts of the rotor. In Fig. #1 the rotor is presented.

Fig. 1 Francis rotor of the Corobicí Project.

The final CAD model generated is presented in Fig. #2. This rotor includes 14 curved blades, with variable thickness along all the surface. The rotor has 2.7 m diameter and it has 0.45 m height.

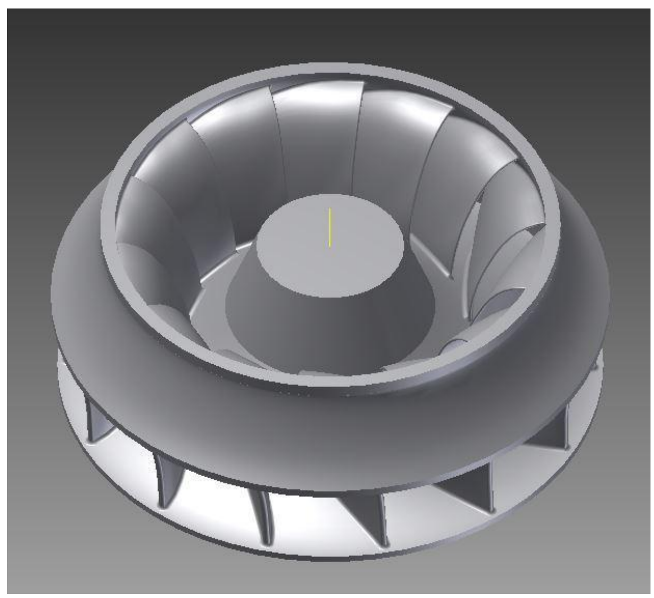

Fig. 2 CAD model of the Corobicí project.

III. CFD MODEL

The computational model used for the CFD simulation describes a incompressible 3D flow, it incorporates a κ-ω turbulent model and a rotational domain in a steady state flow to simulate the turbine operation in zones of high efficiency. Fig. #3 shows the fluid domain, it could be visualized as the complement of the solid rotor domain.

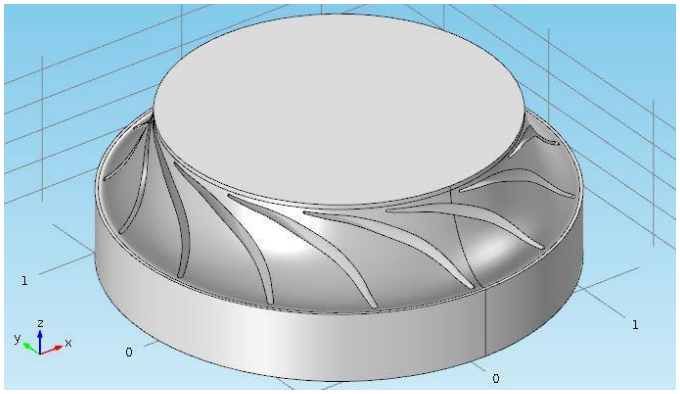

Fig. 3 Fluid domain of the CFD simulation.

Only the rotor domain was simulated, so at the inlet the ideal velocity inlet distribution was assumed. At the outlet some pressure distributions were used without remarkable differences between them, so the most simple was used. In the Fig. #4 the mesh discretization is presented.

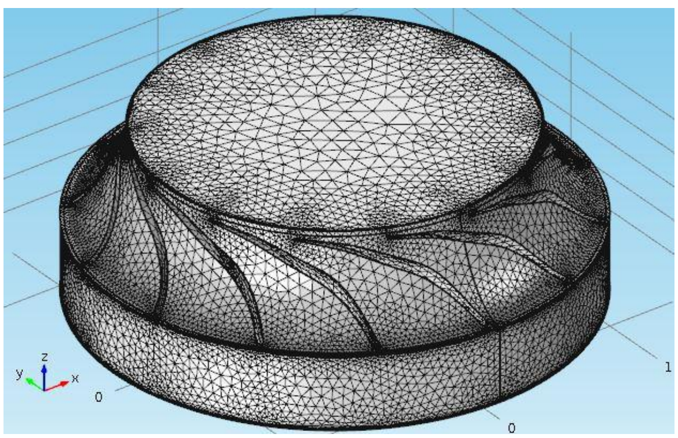

Fig. 4 Fluid domain discretization for the CFD simulation.

First, only two models were carried out, both based on the CAD model showed in Fig. #2. ROD07 is the first and simplest model with no fillets in the blade's edges. ROD07_C is the second and most refined model with fillets in all the blade's edges. Parameters in Table I were taken into account.

IV. RESULTS

The discharge and the efficiency curves can be constructed with the measured properties of the Corobicí turbine. It is showed in the next figures. Fig. #5 shows the discharge's curves of the Corobicí turbine, where it can be observed the completely accordance between this curve and the other 2 curves generated with the ROD07 and ROD07_C models described before.

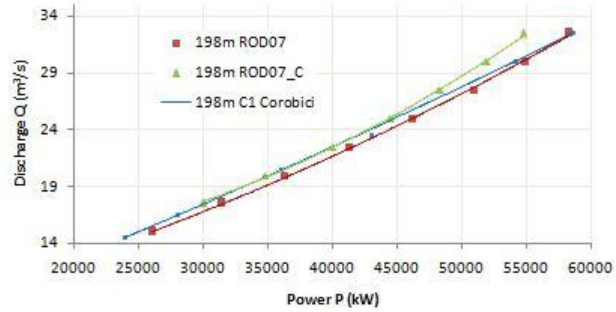

Fig. 5 Discharge curves of the real and simulated turbines.

Fig. #6 shows the efficiency curves of the Corobicí turbine, in which it can be observed a good fit between this curve and the other 2 curves generated with the ROD07 and ROD07_C models described before.

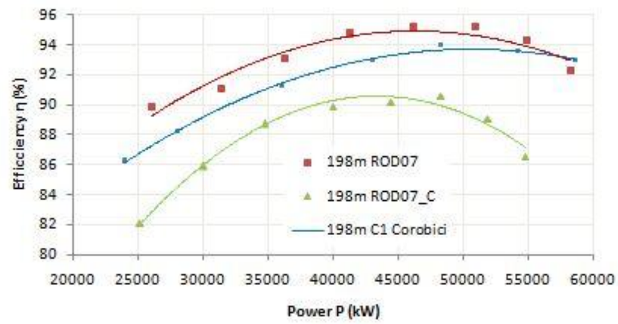

Fig. 6 Efficiency curves of the real and simulated turbines.

V. ANALYSIS & CONCLUSION

Although the agreement in the efficiency curves is not exact, with the progressive refinement of the mesh in the two models, the both curves fits progressively to the Corobicí curve. It is showed that the CFD characterization of the performance properties of a high power scale turbine is feasible and useful.

Future work will include modification in the turbine's design and the corresponding performance characterization, also the structural and dynamic analysis of the rotor.

REFERENCES

[1] R.A. Saeed, A.N. Galybin, V. Popov. (2010). Modelling of flow-induced stresses in a Francis turbine runner. Advances in Engineering Software, Volume 41, Issue 12, December 2010, Pages 1245-1255.

[2] Anup KC, Bhola Thapa, Young-Ho Lee. (2014). Transient numerical analysis of rotor–stator interaction in a Francis turbine. Renewable Energy, Volume 65, May 2014, Pages 227-235.

[3] Li-xiang ZHANG, Wen-quan WANG, Yakun GUO. (2007). Intrinsic features of turbulent flow in strongly 3-D skew blade passage of a Francis turbine. Journal of Hydrodynamics, Ser. B, Volume 19, Issue 1, February 2007, Pages 92-99.

[4] Ru-Zhi Gong, Hong-Jie Wang, Quan-Zhong Liu, Ling-Feng Shu, Feng-Chen Li, *Numerical simulation and rotor dynamic stability analysis on a large hydraulic turbine*, Computers & Fluids, Volume 88, 15 December 2013, Pages 11-18, ISSN 0045-7930.