F5 A CHARACTERIZATION PROCEDURE FOR THE DYNAMIC BEHAVIOR OF FRANCIS TURBINES: PRACTICAL COMPARISON OF ELBOW AND MOODY TYPE DRAFT TUBES

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DISCUSSION

Question by: Bergant, A. (Litostroj)

1. **What was the natural frequency of the inlet conduit of test ring and complete hydrulic system regarding operating conditions?**

2. **Which theoretical approach of prediction of prototype pressure pulsations do you apply with particular emphasize on occurence of system resonance?**

Answer by: Jacob, T.

Mr Bergant's first question can be rephrased in a more general sense: Are there dynamic interactions from the test circuit?
Three boundary conditions must be controlled.

- The pressure side piping was investigated: experimental results presented at the Hydroart conference of June 86 in Genoa, Italy showed the system free oscillations to occur at about 0.5 Hz.

- The suction side piping is dynamically disconnected by the free water level managed in the downstream tank, at the draft tube outlet.

- The rotating masses of runner, shaft and generator rotor resonate with the generator stator field at 40 Hz.

Considering that a typical runner rotation frequency is 10 Hz, significant phenomena occur between 2 and 20 Hz and are not likely to suffer from dynamic interactions from the test circuit.

To answer Mr Mergant's second question, one can say that the standard test procedure indicates the operating conditions and the frequencies for which surging of the draft tube subsystem is liable to occur. This subsystem resonance may be unpleasant, but will probably not be a major nuisance. However, tuning with the upstream piping can lead to unacceptable oscillations. The possible source of trouble being expressed in terms of frequency, modeshape analysis by impedance methods is particularly suited for a theoretical approach to prediction of the full-scale plant stability.

Question by: Nishi, M. (Stanford University)

The discusser would like to have the author's opinion how to choose the position of pressure taps as the standard dynamic testing of a draft tube.

Answer by: Jacob, T.

In answer to Professor Nishi's question, the position of the pressure sensors in the standard test procedure for the determination of the dynamic behavior of Francis turbines is as follows:

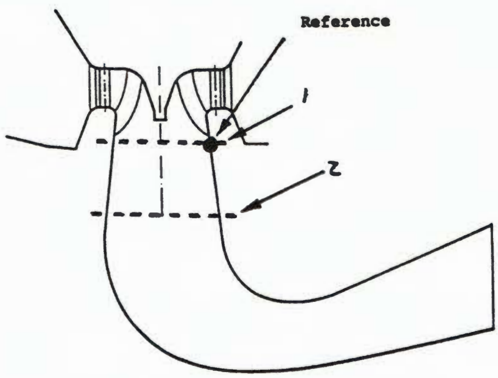
- Two sensors in section 1 of the diagram. These sensors are placed one opposite the other, in the median plan.

- One sensor at the spiral case inlet.

In addition, torque fluctuations are surveyed. These four signals are minimum data for a dynamic analysis. Whenever possible, we also placed

- Additional sensors in Section 1, according to available space
- Three or four sensors in Section 2, to gain insight on the rotating pressure field phenomenon.
- Several sensors in the draft tube elbow for special investigation.
- Additional sensors in the upstream piping for a determination of inlet impedance.

These sensors are piezoelectric transducers, flush-mounted in the draft tube wall.



Question by: Bachmann, P. (Sulzer Escher Wyss)

Can you give some statements to the influence of the different draft tube geometries on performance characteristics especially with respect to the comparison of a Moody cone draft tube with a normal elbow draft tube?

Answer by: Grenier, R.

Model testing showed a substantial efficiency and power drop for the draft tube cone extending up to the runner cone. The drop was less pronounced with the other draft tube cone geometries.

Question by: Pejovic, S. (Mech.Eng. Faculty. Univ. Belgrade)

What is the similarity law in the case of two phase flow under cavitation conditions?

Answer by: Jacob, T.

Professor Pejovic's remark that compressibility of the two-phase flow within the draft tube is greatly incresed, thus possibly impeding the application of similarity laws is most interesting.

In our case, transposition is made possible by the fact that draft tube compressibility can reasonably be assumed to be concentrated in the cavitating vortex core.

Draft tube dynamics may be simplified to an elementary oscillator model, where (Figure 1):

$$C = -1/H \ \partial Vol/\partial\sigma$$

is a lumped capacitance, H being the head and Vol the cavity volume, and

$$L = 1/g \int dl/S$$

is a lumped inertance, if g is the gravity, dl element length and S cross section.

The frequency of free oscillation is then

$$f0 - 1/2\pi \ (CL)^{-1/2}$$

Introducing λ as the ratio of values from prototype to model: $X_p = \lambda X_m$

$$\lambda f_o = (\lambda C \lambda L)^{-1/2} = (\lambda D^3 \lambda\sigma^{-1} \lambda H^{-1} \lambda D^{-1})^{-1/2}$$

where D stands for the runner diameter

$$\lambda f_o \ (\lambda C \lambda L)^{-1/2} = (\lambda D^2 \lambda\sigma^{-1} H \lambda^{-1})^{-1/2}$$

Introducing the runner rotation frequency fn:

$$\lambda fn = (\lambda D^2 \lambda H^{-1})^{-1/2}$$

We find that if Thoma's similitude is respected ($\lambda\sigma = 1$), then $\lambda fn = \lambda fo$ and fo/fn is similar - reserving scale effects - in model and prototype. I would like to insist on the necessity for a proper determination of the draft tube free oscillations frequency. Evolutions versus flow-rate are fully presented in the paper, but influences of Thoma's parameter σ and specific energy are important as well.

Figure 2 shows as an example the evolution of oscillations versus σ at part load (2/3 of best efficiency flow rate). Effects of part load resonance are spectacular on the torque oscillations.

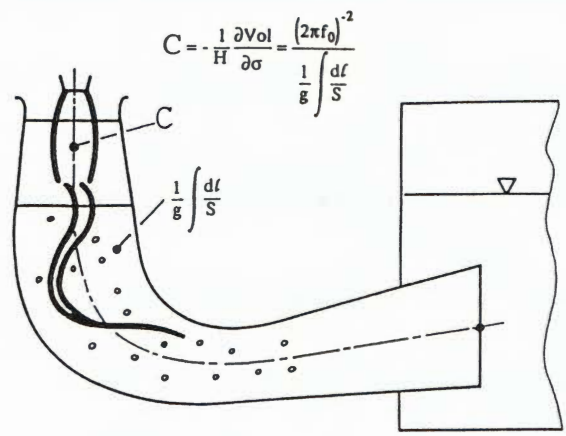


FIGURE 1

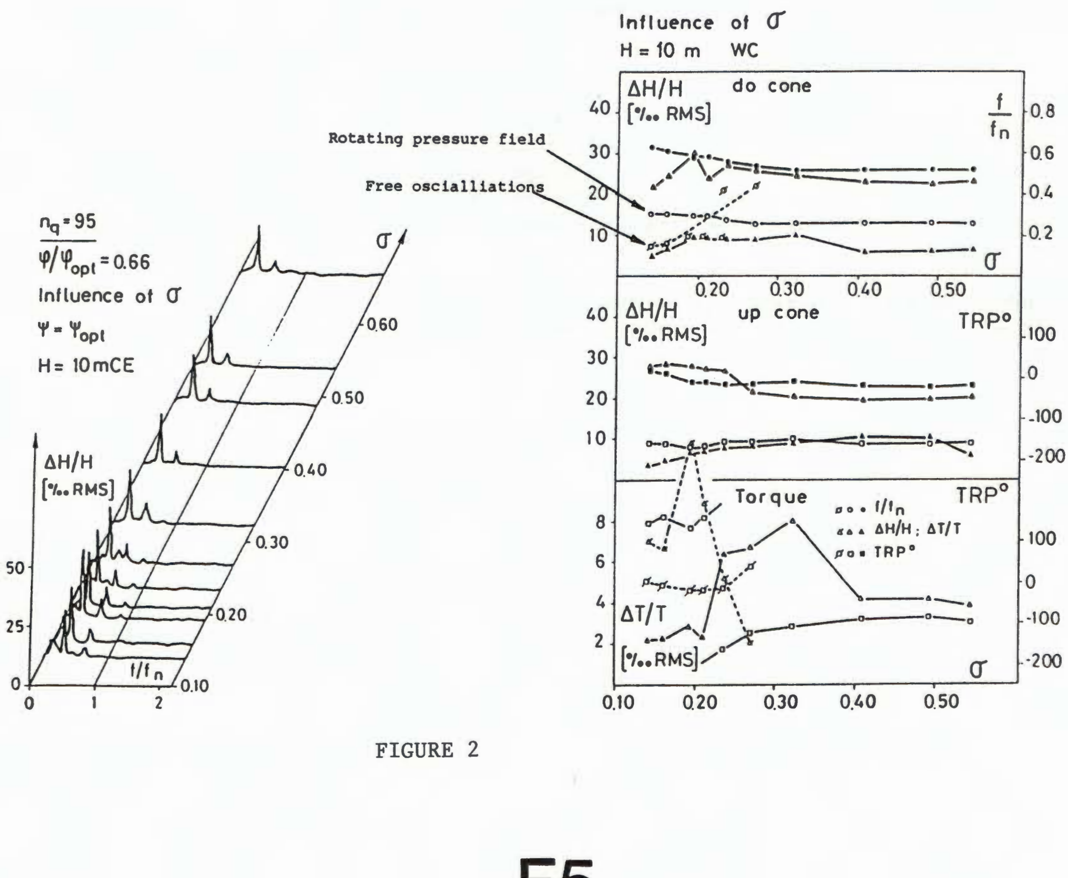


FIGURE 2