EXPERIMENTAL RESEARCH ON VISCOUS FLUID FLOW THROUGH SEALING LABYRINTHS

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Abstract: *This article refers to the results of experimental research regarding the viscous fluid flow through sealing labyrinths of turbo machines. This labyrinths can be met both at the interstice between rotor and housing, and in the zone of the interstice of the balancing disc.*
Within the experimental researches, fluid flows through the labyrinths at different Reynolds numbers were visualized, pressure variations along the length of the labyrinth and increase in rotation speed of the mobile ring were analysed. The experimental results have largely overlapped the numerical ones, confirming that the best geometry for the labyrinth with baffles is the one with equal sizes for the channel’s depth and width.

Keywords*: labyrinths, baffles, viscous flow, turbo machine.*

1. Introduction

Experimental researches complete the numerical analysis of viscous fluid flow through sealing labyrinths, treated in article [1]. This research aims the knowledge of the flow particularities through different forms of labyrinths in order to establish the conditions that interest the mathematical solving of the problem [7]. The experiments were conducted in a facility specially built for the study of laminar movement of liquids, in the Hydraulic Machinery laboratory of the University Politehnica Bucharest.
The experimental stand operates with oils of different viscosities in order to obtain hydro dynamically similar flows after the Reynolds criterion with geometrically larger models of labyrinths, $\delta/\delta' = 100/1000$, for the ease in visualizing the spectra.

2. Experimentally obtained hydrodynamic spectra

Some hydrodynamic spectra of the actual flow of a real liquid through the straight labyrinth (Fig. 1, a) were presented for illustration, for Reynolds numbers between 3 and 35, and through the baffled labyrinth for Re = 15 (Fig. 1, b) and Re = 20 (fig. 1 c).
On this occasion the following characteristics were observed:

- for these flow regimes, vortical cores do not appear at the labyrinths inlets, due to the stabilization phenomenon of the laminar motion, which translates into an additional local pressure loss;
- the occurrence of vortical cores in the baffled labyrinths allows to assess the dependence of sealing effectiveness on the movement regime, depending on the geometry of the labyrinth and flow configuration;
- the only criterion of effectiveness in a labyrinth seal is represented by a configuration as complex as possible of the stream lines and the possibility of vortex formation in certain areas, convenient for a higher braking of the flow.

Since in this flow phenomenon, an important role is played by the rotation velocity of the labyrinth's mobile ring, we designed and realized a variant of a special facility for the investigation of the flow through the labyrinth in real conditions. This facility can work with pressures and peripheral velocities up to the highest permitted in modern design of turbo machinery, due to the hydraulic balancing of the axial force and the stiffening of the shaft.

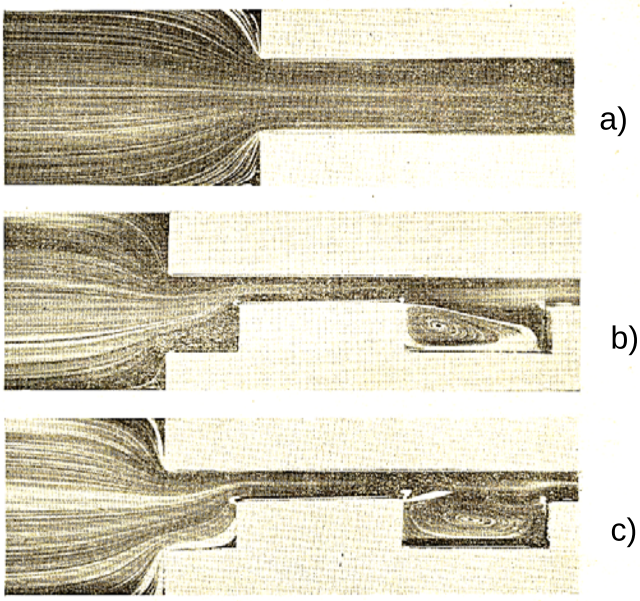

Fig. 1. Hydrodynamic spectra of the 2D movement through the straight labyrinth without and with baffles, as obtained in the facility for the study of viscous fluid flow at a) Re=3…35; b) Re=15; c) Re=20

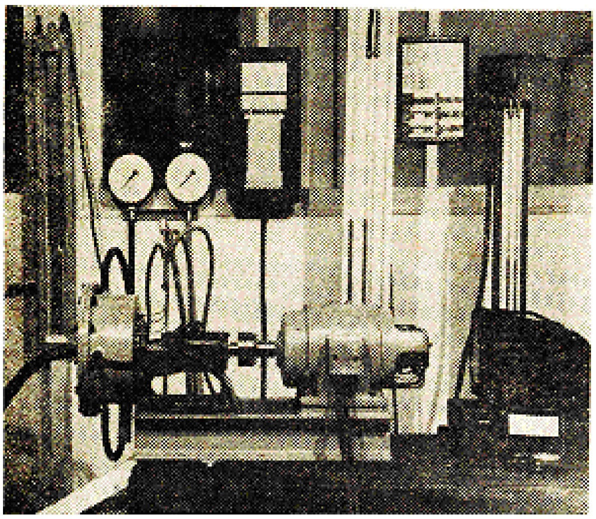

Fig. 2.The stand for experimental tests [6]

The experimental stand allows simultaneous study of two sealing labyrinths of different shapes (Fig. 2).
The pressure in the system was carried out by a multistage centrifugal pump. Pressure plugs were practiced in the fixed ring of the labyrinth, for a good knowledge of the pressure distribution along the labyrinth.
Due to the relatively small sizes of the labyrinths, a particular attention was given to respecting their shape and size, surface quality, and the outer ring and inner balance.

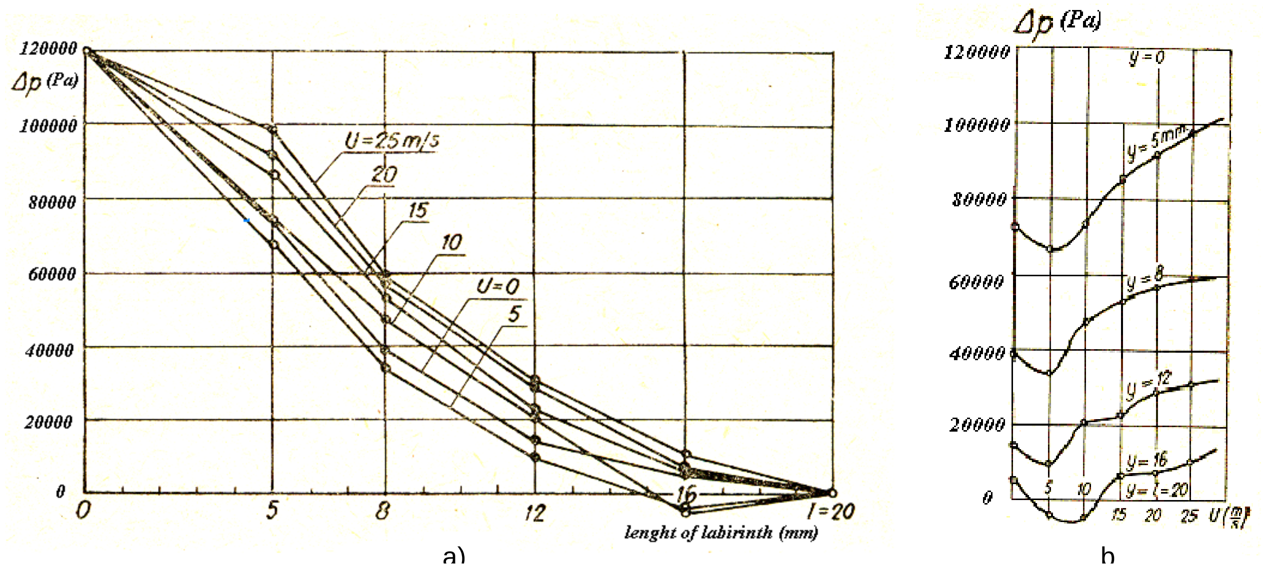

Fig. 3. Pressure variation: a) along the labyrinth; b) at different rotation velocities of the mobile ring [6]

In Figure 3 a) is shown the variation of pressure along the labyrinth l (mm), and Figure 3 b) shows the variation of pressure at different rotational velocities U (m/s), results from tests made with water. These studies have revealed the influence of the rotation velocity of the labyrinth’s mobile ring on its sealing capacity.
The minimum sealing capacity occurs approximately at the value of 1 of the rotational velocities coefficient [6], which is a general phenomenon in the theory of hydrodynamic similarity, and which corresponds to a qualitative change of the movement.

3. Comparative analysis: CFD and experiments

From a comparative analysis of pressure variations resulting from numerical simulation and those obtained experimentally, values represented in Figure 4, one can see the intersection of values for most of the labyrinth’s length, with values slightly different at the inlet and outlet of the labyrinth. We obtained stable numerical solutions at low rotation velocities (0.5 or 10 m/s). This values clearly overlapping on the values obtained experimentally.

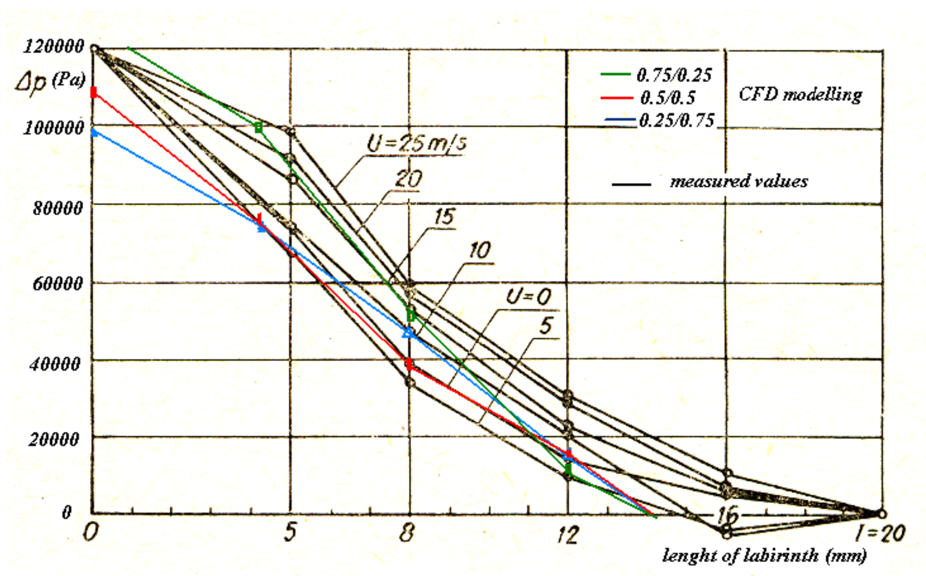

Fig. 4 Numerical and experimental results for fluid flow through turbo machines labyrinths

This comparison also revealed that the greatest areas overlap was found for the labyrinth with the geometric ratio 0.5 / 0.5, i.e. equal values of the depth, width and stepof the baffles.

4. Conclusions

Numerical modelling of a viscous fluid flow through turbo machines labyrinths led to the following observations: the flow velocities varies between the inlet and outlet of the labyrinth in all three geometries studied; as the depth of labyrinth's baffle increased, velocities were reduced along the labyrinth; approximate equal values of velocity were registered for a depth of the channel equal to the width (in parametric design 0.5/0.5). This together with the 0.4/0.6 depth to width ratio design would represent the optimal configurations of the labyrinths.
The pressure drop along the labyrinth was different, more rapid at deeper baffles. Stream lines spectrum revealed formation of vortices in the flow in the area of labyrinth baffles, as the viscous fluid flow passes through them, providing the labyrinth sealing. Stable numerical solutions were obtained for small rotational velocities (0, 5 or 10 m/s).
In the experimental research flows at different Reynolds numbers were visualized, pressure variations along the length of the labyrinth were analysed and the increase in rotational velocity of the mobile ring. The numerical results overlapped largely over the experimental ones.
These observations led us to conclude that an optimal labyrinth with baffles has the depth of baffles at most equal to the width of the channel of flow in the labyrinth, and the step of baffles equal to this depth.
Similar numerical and experimental approaches were identified in articles [2-5].
This research will be extended by further investigations regarding the effect of geometry on the increase in hydraulic efficiency of turbo machines.

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