BULETINUL ŞTIINŢIFIC
al
Universităţii „POLITEHNICA” din Timişoara, România

Seria MECANICĂ

SCIENTIFIC BULLETIN
of
the „POLITEHNICA” University of Timişoara, Romania

Transactions on MECHANICS

Tomul 55(69), Fascicola 2, 2010
ISSN 1224-6077

EDITURA POLITEHNICA

Editor-in-Chief
Assoc. Prof. PhD. Eng. Mihaela POPESCU,
Politehnica University of Timişoara, Romania

Associate Editor-in-Chief
Assoc. Prof. PhD. Eng. Aurel RADUTA
Politehnica University of Timişoara, Romania

Editorial Board

Prof.PhD. **Francois AVELLAN**,
Ecole Polytechnique Federale de Lausanne, Suisse
Prof.PhD.Eng. **Mircea BĂRGLĂZAN**,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. **Liviu BERETEU**,
Politehnica University of Timişoara, Romania
Prof.PhD. **Didier BOUVARD**,
Institut National Polytechnique de Grenoble, France
Prof.PhD.Eng. **Waltraut BRANDL**,
University of Gelsenkirchen, Germany
Prof.PhD.Eng. **Burkhard CORVES** ,
RWTH Aachen, Germany
Prof.docent dr.ing. **Arpad A. FAY**,
University of Miskolc, Hungary
Prof.dr. **Pier Giorgio FEDOLFI**,
IFOA Regio Emilio, Italiy
Prof.PhD.Eng.**Traian FLEŞER**,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng.**Tudor ICLĂNZAN**,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. habil **Ioana IONEL,**
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. **Eugen ISBĂŞOIU**,
University of Bucharest, Romania
Sen. lecturer **Herbert JELINEK**,
Charles Sturt University, USA
Prof.PhD.Eng. **Inocenţiu MANIU**,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. **Livius MILOŞ** ,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng.**Vasile NĂSTĂSESCU**,
Academia Tehnică Militară, Bucureşti, Romania
Prof.PhD.Eng. **Zbiniew OLESIAK**,
Technical University of Opole, Poland
Conf.dr.ing. **Aurel RĂDUŢĂ**,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. **Laszlo POKORADI**,
University of Debreceni, Hungary
Prof.PhD.Eng. habil **Winfried Maria RUSS,**
Technical University of Munchen, Germany
Prof.PhD.Eng. habil **Peter STURM,**
Technical University of Graz, Austria
Prof.PhD.Eng. **Viorel-Aurel ŞERBAN**,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. **Dumitru ŢUCU,**
Politehnica University of Bucharest, Romania
Prof.PhD.Eng. **Nicolae VASILIU,**
Politehnica University of Bucharest, Romania

Editorial Secretary
Assoc. Prof. PhD. Eng. Emilia Georgeta MOCUŢA
Politehnica University of Timişoara, Romania

Reviewers

Prof..PhD..Eng. **Liviu Eugen ANTON**,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. **Alexandru BAYA**,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. **Liviu BERETEU,**
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. **Waltraut BRANDL**,
University of Gelsenkirchen, Germany
Prof.PhD.Eng. **Florin BREABĂN**,
Université Artois IUT Bethune, France
Prof.PhD.Eng. **Victor BUDĂU**,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. **Gheorghe DRĂGĂNESCU**,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. **Ion DUMITRU,**
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. **Traian FLEŞER**,
Politehnica University of Timişoara, Romania
Assoc.Prof.PhD.Eng. **Erwin-Christian LOVASZ**,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng.habil **Ioana IONEL**,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. **Mihai JĂDĂNEANŢ**,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. **Ion MITELEA**,
Politehnica University of Timişoara, Romania
Assoc.Prof.PhD.Eng. **Georgeta Emilia MOCUŢA**,
Politehnica University of Timişoara, Romania
Assoc.Prof.PhD.Eng. **Mihaela POPESCU**,
Politehnica University of Timişoara, Romania
Assoc.Prof.PhD.Eng. **Aurel RĂDUŢĂ**,
Politehnica University of Timişoara, Romania
Assoc.Prof.PhD.Eng. **Daniel STAN**,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. **Viorel-Aurel ŞERBAN,**
Politehnica University of Timişoara, Romania
Assoc.Prof.PhD.Eng. **Dănuţ ŞOŞDEAN**,
Politehnica University of Timişoara, Romania
Prof.PhD.Eng. **Marin TRUŞCULESCU**,
Politehnica University of Timişoara, Romania

CONTENTS

SCIENTIFIC BULLETIN OF
THE „POLITEHNICA" UNIVERSITY OF TIMISOARA, ROMANIA
TRANSACTIONS ON MECHANICS
BULETINUL ŞTIINȚIFIC AL
UNIVERSITĂȚII „POLITEHNICA" DIN TIMIŞOARA, ROMÂNIA
SERIA MECANICĂ
Vol. 55(69) ISSN 1224 - 6077 Iss. 2, 2010

DESIGN, NUMERICAL ANALYSIS AND PRACTICAL IMPLEMENTATION OF A FLOW-FEEDBACK SYSTEM FOR CONICAL DIFFUSER WITH SWIRLING FLOW

Constantin TĂNASĂ*, Romeo SUSAN-RESIGA*, Alin I. BOSIOC*, Sebastian MUNTEAN**
* Department of Hydraulic Machinery, "Politehnica" University of Timişoara, Bv. Mihai Viteazu, No. 1, Timişoara, RO-300222, România. Tel.: +40 256 403692, Fax: +40 256 403692.
E-mail: costel@mh.mec.upt.ro, resiga@mh.mec.upt.ro, alin@mh.mec.upt.ro
** Centre for Advanced Research in Engineering Sciences, Romanian Academy – Timişoara Branch, Bv. Mihai Viteazu, No. 24, RO-300223 Timişoara, România, e-mail: seby@mh.mec.upt.ro

Abstract.
The conical diffuser (discharge cone), is an essential component of the hydraulic turbines, which converts the excess of kinetic head at runner outlet into static head, thus reducing the hydraulic losses in the draft tube. When the turbine operating far from the best efficiency point, the swirling flow in the discharge cone becomes unstable, with large pressure fluctuations and with increased of hydraulic losses. A new method for swirling flow control has been developed by Resiga et al. [8] using a water jet injection along the cone axis. The present paper describes an efficient approach for supplying the control jet, using a flow-feedback method. We describe the actual implementation of the flow-feedback, using a twin spiral case installed at the cone outlet. Both design considerations and numerical analysis are presented, as well as technical details for the implementation. A first set of experimental results clearly show the benefits of our flow-feedback system. This method eliminates the swirling flow and associated pressure fluctuations by supplying the jet with water from downstream of draft tube cone, without reducing the turbine efficiency, and without additional energy input.

Keywords: hydraulic turbines, diffuser, swirling flow, flow-feedback

1. Introduction

The researches in the swirling flow domain in the draft tube cone, today is necessary, because the hydraulic turbines with fixed blades (like Francis turbines), are imposed to work in a large scale of regimes. At partial discharge the flow downstream the runner of a Francis turbine evolves in a precessing helical vortex (or vortex rope), with high amplitude pressure pulsation.

The vortex rope has badly effects on the energy performance of the turbine, also has bad effect leading in time to cracking or breaks the blades, and damage of the machine bearings, respectively.

An important component of the turbines with low and medium had is the hydraulic draft tube, because this is responsible in a big proportion of the hydraulic losses in the system. Also the efficiency of the turbine is significantly affected by the performance of the draft tube. The shape and distribution of velocity field at the inlet is influenced by some factors which affect the draft tube performance. The flow in the draft tube can be outlined by the Bernoulli's equation between inlet and outlet section, respectively:

$$\frac{p_1}{\rho g}+z_1+\frac{\alpha_1 v_1}{2g}=\frac{p_2}{\rho g}-z_2+\frac{\alpha_2 v_2}{2g}+h_f \qquad (1)$$

Where p is absolute pressure, z the height, α kinetic energy correction factor, v the mean velocity, and h_f the hydraulic losses in the draft tube.

The appearance of the vortex rope has a strong connection with the operation mode of the turbine at different flow rates [12]. Jacob, in his PhD. thesis [4], show, as vortex rope appears at various flow rates regimes, but the consequences of vortex appear just at part load.

Current research allowed accomplishment of test rigs and development of methodology that will lead to reducing or even eliminating the vortex rope. The method developed by Thike et al. [11], which requires the introduction of air or water vapours in the vortex, leading to a decrease of pressure pulsations, but the disadvantage is the high cost of energy to compress the air, and the sealing to be done. Another method used by Kurokawa et al. [6], requires installation of channels on the axis of draft tube cone, the effect is to reduce the flow with rotation up to 85%, with disadvantage that it increases the stagnation zone, and appear instabilities. Nishi et al. [7], use the Vortex Generator Jet method, which involving the introduction of tangential jets in the draft tube cone, with a slope of 14° of this. This method involved big costs of implementation. Kirschner et al. [5] developed a test rig for swirling flows investigations in the conical diffuser, with a swirl generator, which presents adjustable blades, and with air introduction to emphasize the cavitating vortex rope, respectively. They do pressure, velocity measurements, and numerical simulation, respectively. From comparisons between experimental and numerical, result a good agreement between them. Ciocan et al. [2], investigate the swirling flow on a real turbine model in the FLINDT project (Figure 1). On that model they did measurements of velocity profiles with LDV, measurements of velocity field with PIV, and measurements of pressure pulsation on the draft tube cone wall, respectively. In parallel with experimental investigations they did numerical 3D simulation, and the comparison of results led to a good validation between them.

By examine the swirling flow which appear in the draft tube cone of Francis turbine, when is at part load, Susan-Resiga et al. [8], supports the introduction of a new system to control the swirling flow which involves the reducing or even eliminating the effects of pressure pulsation and the stagnant zone, by injecting an axial water jet along the runner crown.

The advantages of this solution compared with others that relate to the same problem, are: it successfully addresses directly the main causes of the flow instability, rather than the effects; it does not require geometrical modifications of the runner, and no other devices need to be installed in the draft tube; it is continuously adjustable according to the operating point, and it can be switched-off when it is not needed; the practical implementation is simple and robust.

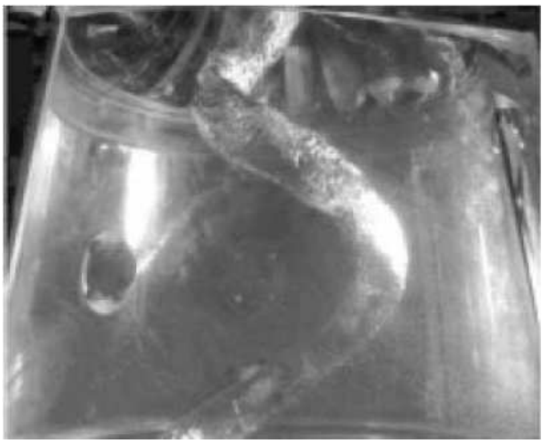

Figure 1 Vortex rope in the FLINDT project.

But this method use for supply the jet 10% from the flow discharge to eliminating the stagnant region, and this water is taking from upstream with an auxiliary energy source, also this method bring volumetric losses in the system and with an decrease of efficiency turbine.

The answer at the question how we can supply the jet without any additional energy input, and without reducing the turbine efficiency, led to a first conclusion, namely, we can observe by examine the swirling flow in draft tube cone of Francis turbine, at part load an excess of static and total pressure on the cone wall. This conclusion led Resiga et al. [9], [10], to introduce a new flow-feedback system (Figure 2) by means a part of the flow is collected from downstream of the cone wall, and redirecting to upstream, for eliminating the swirling flow, by injecting it at the end of the crown. This system does not require any additional energy input, and the turbine efficiency is preserved by the fact that the jet produced is strong enough to remove the stagnant region. Figure 2 shows a comparison between the swirling flow in the conical diffuser without and with flow-feedback. It is clear that the flow feedback mechanism generates a control jet which successfully eliminates the stagnant region, thus stabilizing the swirling flow.

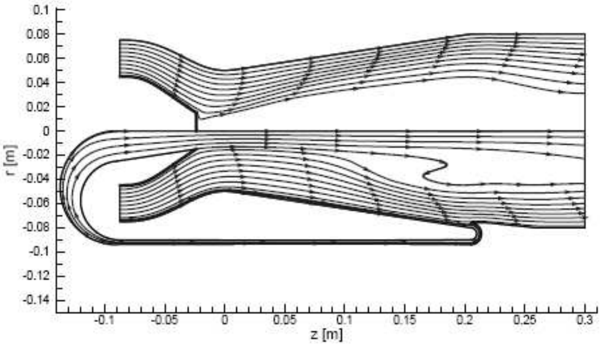

Figure 2 Streamlines for the axisymmetric swirling flow without flow control (upper half-plane) and with flow feedback control (lower half-plane) [10]

2. Design and numerical analysis of the twin spiral case.

Susan-Resiga et al [8], introduce a new method of swirling flow control, which mitigate the precessing vortex rope, and his pressure fluctuations, by introduction of an axial water jet along the draft tube cone. For this is necessary 10% of discharge flow, to remove the central stagnant region of vortex rope. This flow is obtained by implementing into the system an auxiliary energy source, which takes water from upstream. The disadvantage of this method requires the introduction of volumetric losses into the system, by implementing the auxiliary energy source, to supply the jet from upstream. To eliminate this deficiency, Susan-Resiga et al [9], came with a new solution for supply the jet. The proposal solution involves, taking that flow which supply the jet, from downstream of draft tube cone, by introduction of a spiral case at the end of the cone, through a by-pass system, which take this flow and introduce him at the end of crown. The name of entire system is flow-feedback.

The first step was to design an ordinary spiral case. The spiral casing is one of the main components of hydraulic turbines, which linked the pressure-gallery with guide vane.

The design of spiral case, on the first phase involved the achieved of radial sections, which will determine the spiral case envelope. The sections radius, was determined from the maximum R_{max} = 16.5mm, and minimum R_{min} = 4mm, radius respectively. The maximum radius is determined from the pipes which are mounted on the test rig to supply the jet, and represent the outlet dimension of spiral case. The minimum radius is from 2D axisymmetric flow-feedback simulation obtained by Resiga et al [10]. With these two values, was determined the radius of each section respectively:

$$R(\theta)=\sqrt{R_{\min}^{2}+\frac{(R_{\max}^{2}-R_{\min}^{2})(\theta-\pi/9)}{8\pi/9}}, \qquad (2)$$

θ = [rad]

On a domain of 180° was chosen the calculation of 17 sections. After obtained the radius values, the sections were made. Each section was rotated by an angle θ of 10°, resulting one half of spiral case envelope (except the minimum section which were rotated by an angle θ of 20°, to represent the tongue of spiral case). This half of spiral case was rotated with 180°, achieving the entire spiral case, plus the exit pipes with a length of 105mm. Figure 3 shows the constant increasing of radius of each section in direct proportion with θ, and Figure 4a,b, shows a longitudinal cross-section of the final spiral case assembled with test section presented by Bosioc et al.[1], and the radial section of the spiral case in detail, respectively.

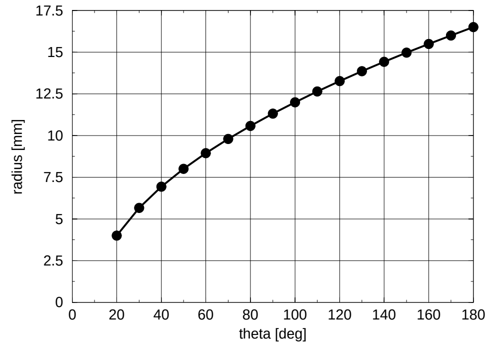

Figure 3 The dependence between θ and radius of each section.

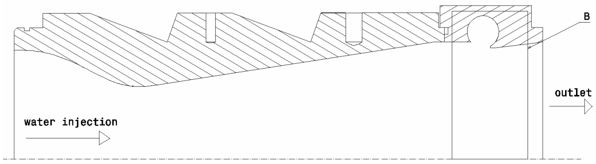

Figure 4a) Longitudinal cross-section of the assembly between test section and twin spiral case.

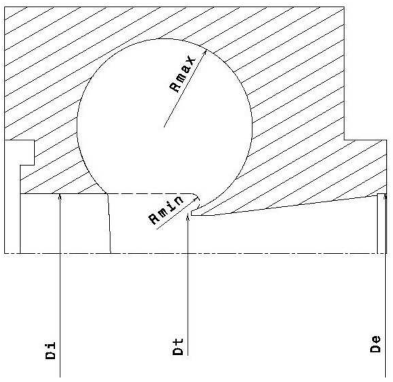

Figure 4b) Radial section of the twin spiral case (detail).

In Figure 4a we observe the water injection along the axis of a convergent-divergent section trough spiral case, and goes out by the outlet. The radial section (Figure 4b), of spiral case haves an inlet diameter with a value of D_i =160mm, a tongue diameter D_t = 152mm, and an outlet diameter D_e = 160mm, respectively.

From hydraulic point of view, the losses along the spiral case its have to be minim. To determine the hydraulic losses in the spiral case has made a numerical 3D analysis with FLUENT 6.3 software [3]. The analysis domain was made in Gambit 2.4 [3], with a total of approximately 47+e4 elements, with quadrilateral and tetrahedral structure (Figure 5).

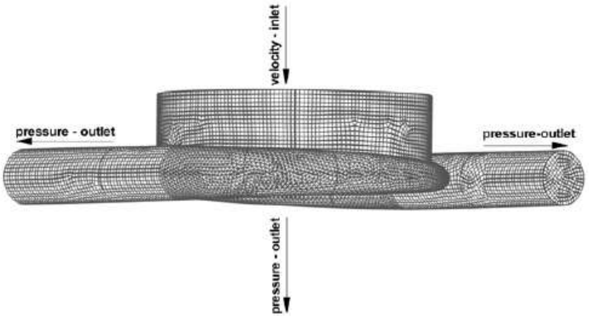

Figure 5 Analysis domain and boundary layers.

The boundary layers assumed to impose a velocity profile at the inlet, pressure-outlet plus radial equilibrium at the downstream exist, and constant pressure on the exit pipes with an increase of pressure from 100, 200…500, 1000, 1500, 2000 Pa. The flow was assumed to be unsteady turbulent, with a k-ε model. The exit pipes of the analysis domain have 130mm length, than the design domain that has 105mm, because of stabilizing the solution. The velocity profiles (Figure 6), used for inlet boundary conditions, was removed from outlet of the 2D axysimmetric flow-feedback analysis [10], and they are dimensionless with respect the throat velocity (Eq.4), and the dimensionless radius respect the throat radius with a value of 0.05m

$$V_{throat} = Q / \pi R^2 \qquad (3)$$

where: Q is the main discharge.

Figure 7 shows the dependence of the flow on the pipes exit, and the pressure of pipes exit, where we observe a decrease of the flow in the spiral case with increase of the pressure on the exit pipes. From the velocity profile imposed at the inlet, the flow is Q = 33.6 l/s, and at the downstream exit the flow is 30.7 /s. The rest of 2.9 l/s is distribute on the exit pipes, at 2000 Pa pressure. This value of the flow represents approximately 10% from the main flow as much is necessary to supply the jet.

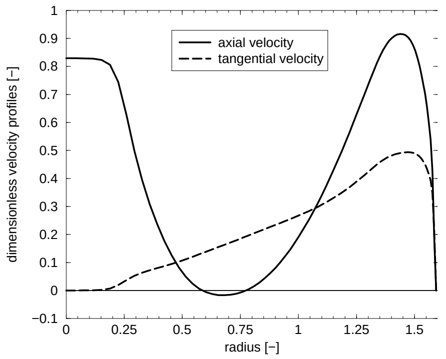

Figure 6 Axial and tangential velocity profiles from 2D axisymmetric flow-feedback simulation at the exit of spiral case.

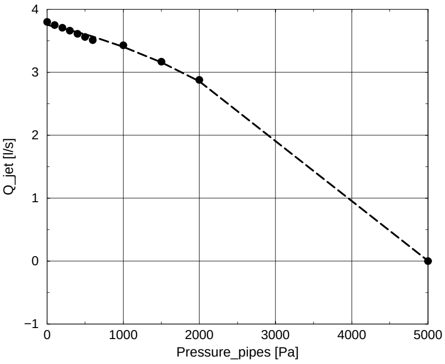

Figure 7 The flow on the pipes exit depending on the pressure of the exit pipes.

The next step was to analyse the average tangential velocity of domain with 2000 Pa at the exit pipes, as:

$$V_{\theta_{aver}} = \frac{1}{A}\int V_{\theta_{aver}}(\theta)dA \qquad (4)$$

For this was made 7 radial sections, along the spiral case, at θ = 30° angle (Figure 8).

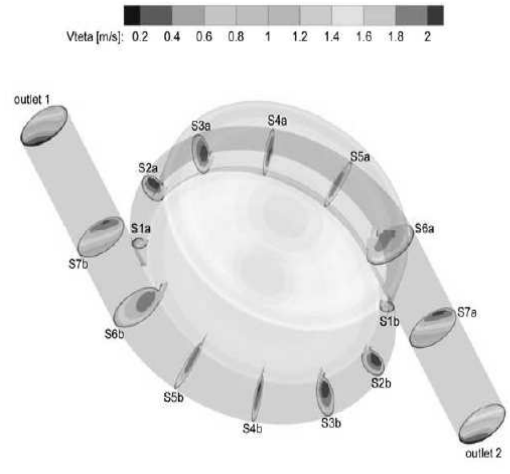

Figure 8 The radial sections of spiral case to analysis of average tangential velocity.

Figure 9 presents the dimensionless average tangential velocity depending on the θ angle. The dimensionless of average tangential velocity was done by respecting the throat velocity. We observe the maximum value of the average tangential velocity at the section of 30° angle, and with a slow decrease along the spiral case to the exit pipes, because didn't exist a strong tangential component to the exit.

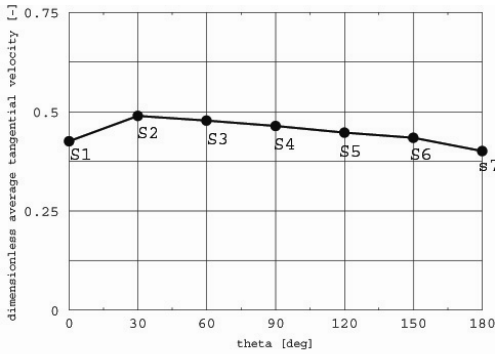

Figure 9 The dependence between average tangential velocity and radius of each section.

The analysis domain of spiral case was exported into CATIA v5R16, to design the final spiral case for the flow-feedback system (Figure 10).

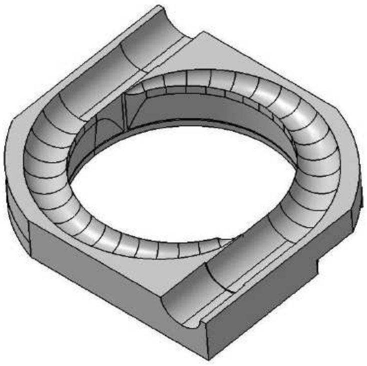

Figure 10 Spiral case section.

3. Practical implementation.

The spiral case is consists from two parts with two exit pipes. The exit pipes will be linked with two pipes, which will supplies the jet. The inlet into spiral case is Φ = 160mm at upstream, and Φ = 152mm at the tongue respectively. The radial opening of the slit with a value of 4mm, allow collecting the water from the cone wall, taking into account that water is pushed to the wall because of tangential component, which is due out to the runner. The final spiral case (Figure 11), was made by rapid-prototyping machine, with an overall size of 230x210x70mm.

Making and implementing the system on the test rig, assumed to introduce two copper pipes of 35mm in diameter into the spiral case exits, which will linked by an flexible connector with two valves for opening and closing the jet supply, respectively (Figure 12).

Figure 11 Spiral case made by rapid-prototyping machine.

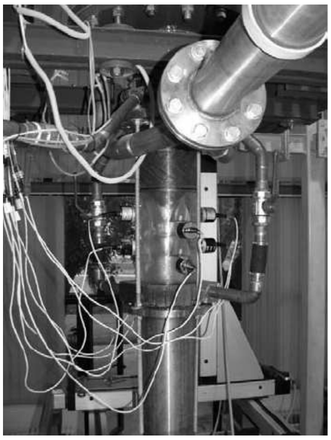

Figure 12 Implementing the flow-feedback system on the test rig.

4. Results and conclusions.

The main scope of the flow-feedback system is to take a fraction of the discharge from downstream cone wall, and injected upstream along the axis without any additional energy input for mitigate the quasi-stagnant central region associated with the vortex rope. Figure 13 shows the wall pressure recovery vs. length of the cone:

$$\Delta p = p_{average} - p_{throat} \qquad (5)$$

where: $p_{average}$ is the average pressure measured by the pressure transducers on the cone wall, p_{throat} is the pressure at the inlet in the cone.

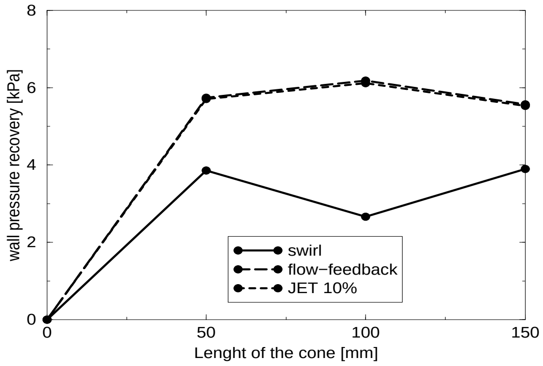

Figure 13 Wall pressure recovery.

From the first experimental measurements we observe that flow-feedback method have approximately the same pressure recovery on the wall, like the jet method at 10%, with the main discharge at 30l/s used by Bosioc et al. [1], and is obvious that pressure recovery on the wall becomes higher with these methods over the swirling flow. It is envisaged to make experimental measurements on pressure and velocity field, with and without flow-feedback method, respectively.

Acknowledgment

This work has been supported by Romanian National University Research Council under The Exploratory Research Project 799/2009, and partially supported by the strategic grant POSDRU 6/1.5/S/13 (2008) of the Ministry of Labour, Family and Social Protection, Romania, co-financed by the European Social Fund – Investing in People.

References

1. A.I. Bosioc, R. Susan-Resiga, S. Muntean *Unsteady pressure measurements in a conical diffuser with swirling flow* [Conference] // Proceedings of the 4th Workshop on Vortex Dominated Flows / ed. Georgescu A.M., Georgescu S.C. and Bernad S.I.. - Bucharest, Romania, Scientific Bulletin of the Politehnica University of Timişoara, Transaction on Mechanics, 2008, Tom 53(67), Fasc.3, pp. 81-89, ISSN 1224-6077
2. G.D. Ciocan, M.S. Iliescu, T.C. Vu, B. Nennemann, F. Avellan, *Experimental study and numerical simulation of the FLINDT draft tube rotating vortex* [Journal] // Journal of Fluids Engineering, 2007, Vol. 129, pp. 146-158, ISBN/ISSN 3-540-00739-3
3. *** Fluent 6. *User's Guide*, Fluent Incorporated [Book], 2001
4. T. Jacob, *Evaluation sur modele reduit et prediction de la stabilite de fonctionnement des turbines Francis* // Phd thesis, Ecole Politehnique de Lausanne, Switzerland, 1993
5. O. Kirschner, J. Grupp, H. Schmidt, *Experimental investigation of vortex control in a straight draft tube model* [Conference] // 4th German-Romanian Workshop on Turbomachinery Hydrodynamics, Stuttgart, Germany, 2008
6. J. Kurokawa, A. Kajigaya, J. Matusi , H. Imamura, *Suppression of the swirl in a conical diffuser by use of J-Groove* [Conference] // Proceedings of 20th IAHR Symposium on Hydraulic Machinery and Systems. – Charlotte, North Carolina, U.S.A. 2000, ISBN 3-530150-20-4
7. M. Nishi, K. Yoshida and K. Morimitsu, *Control of separation in a conical diffuser by vortex generators jets* [Journal] // JSME International Journal, Series B, 1998, Vol. 41, pp. 233-238, ISBN 07918 36738
8. R. Susan-Resiga, T.C. Vu, S. Muntean, G.D. Ciocan, B. Nennemann, *Jet control of the draft tube vortex rope in Francis turbines at partial discharge* [Conference] // Proceedings of the 23rd IAHR Symposium on Hydraulic Machinery and Systems, Yokohama, Japan, 2006, pp. 192, ISBN 3-930150-30-4
9. R. Susan-Resiga, S. Muntean, *Swirling flow apparatus and test rig for flow control in hydraulic turbines discharge cone* [Conference] // Proceedings of 2nd IAHR International Meeting of the Workgroup on Cavitation and Dynamic Problems in Hydraulic Machinery and Systems, Scientific Bulletin of the Politehnica University of Timişoara, Transactions on Mechanics, 2007, Tom 52(66), Fasc. 6, pp. 203-207, ISSN 1224-6077
10. R. Susan-Resiga and S. Muntean, *Decelerated swirling flow control in the discharge cone of Francis turbines* [Conference] // The 4th International Symposium on Fluid Machinery and Fluid Engineering, Beijing, China: Ed. Springer, 2008, pp. 89-96, ISBN 978-85-60858-13
11. R. H. Thike, *Practical solutions for draft tube instability*, Water Power and Dam Construction, 1981, Vol. 33, No. 2, pp. 31-37, ISSN 1467-2715
12. A. Zobeiri, *Investigations of time dependent flow phenomena in a turbine and a pump-turbine of Francis type: rotor-stator interactions and precessing vortex rope* // PhD thesis, Ecole Polytehnique Federale de Lausanne, Switzerland, 2009, pp. 12-20, ISSN 1051-6223

PROIECTAREA, ANALIZA NUMERICĂ ŞI IMPLEMENTAREA PRACTICĂ A SISTEMULUI FLOW-FEEDBACK PENTRU CURGEREA CU VÂRTEJ ÎN DIFUZORUL CONIC

Rezumat

Difuzorul conic (conul tubului de aspirație), este o componentă esențială a turbinelor hidraulice, care trasformă excesul de energie cinetică de la ieşirea din rotor într-una statică, reducând astfel pierderile hidraulice în tubul de aspirație. Când turbina funcționează departe de punctul optim de funcționare, curgerea cu vârtej din conul tubului de aspirație devine instabilă, cu mari fluctuații de presiune şi cu creşterea pierderilor hidraulice. O nouă metodă de control a curgerilor cu vârtej a fost dezvoltată de Resiga et al. [9] folosind injecție de apă de-alungul axei conului. Lucrarea de față prezintă o metodă eficientă de alimentare a jetului, folosind o metodă tip flow-feedback. Se descrie implementarea sistemului flow-feedback, introducând o cameră spirală geamănă la ieşirea din con. Se prezintă atât proiectarea şi analiza numerică, cât şi detalii tehnice de implementare. Primele rezultate experimentale arată clar beneficiile sistemului flow-feedback. Cu această metodă se elimină curgerea cu vârtej şi fluctuațiile de presiune asociate acesteia prin alimentarea jetului cu apă din avalul conului tubului de aspirație fără a reduce randamentul turbinei şi fără a introduce o altă sursă de energie.

Scientific reviewers: **Liviu Eugen ANTON*,"POLITEHNICA" University of Timişoara, Romania**
Teodor MILOŞ* " POLITEHNICA " University of Timişoara, Romania