DAMPING OF THE PRESSURE PULSATIONS IN THE VANELESS SPACE OF THE PUMP TURBINE

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ABSTRACT

This paper is focused on the dynamical damper research of the high frequency pressure and flow pulsations in the vaneless space of the pump tubine. This pulsations rise as a result of the interaction between the impeller and distributor.

From the theory is generally known, that the dynamical damper based on the Helmholtz resonator principle is placed into the antinodes of the pressure eigen wave shape, if the standing wave is assumed. The eigen and excitated wave shapes were determined by the transfer matrix method. The one-dimensional theory and the second viscosity were assumed.

1. COMPUTATIONAL METHOD

Transfer matrix with influence of second viscosity and material damping was employed for computation of pressure pulsations for different frequencies and positions. Second viscosity represents frequency dependant damping, which has be taken into account when we describe damping on higher frequencies. Influence of runner on high-frequency pulsations was considered in the presented paper

2. MATHEMATICAL MODEL OF THE TURBINE WITH PENSTOCK

Fig.1 depicts turbine model with penstock and draft tube. Node 1 models the space below runner; nodes 2-21 characterize water entering the runner during turbine mode of operation and nodes 22-41 model water leaving the wicket gates. It means that nodes 2-41 describe the vaneless space. Nodes 42-62 describe outflow from spiral casing to wicket gates. These nodes are followed, in turbine mode of operation (i.e. in clockwise direction), by spiral casing pipes with step reduction of cross-section. Node 64 models boundary condition of the tailwater reservoir with constant pressure and so does the node 66 for upper reservoir. Discharge boundary condition is prescribed in the remaining nodes; it means that continuity equation must be fulfilled in these nodes.

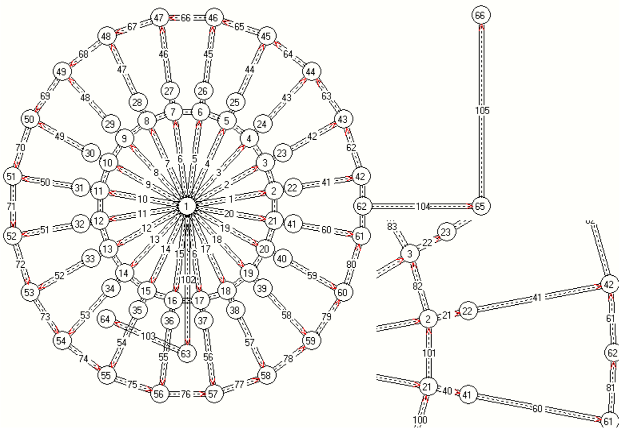


Figure 1: *Mathematical model*

Pipes 1-20 model runner, pressure jump of the shape corresponding to the combination of runner blade number and wicket gates number is modeled in pipes 21-40,. In this case: 7 runner blades, 20 wicket gates. This combination gives eccentric distribution along the vaneless space circumference, which rotates in runner direction with 21 times the runner frequency.

Pipes 41-60 model the space between the wicket gates ad pipes 61-81 model spiral casing, these pipes have gradually increasing cross-section corresponding to increasing cross-section of spiral casing in the given position. Pipes 82-101 describe vaneless space. Pipes 102-103 depict draft tube and pipes 104-105 model penstock.

Overview of the model

Model parameters are summarized in table below

Pipe index …. according to Fig.1

Cross-section … pipe inner diameter

v fluid celerity

R[1] linearized resistance against motion at the pipe beginning

ζ second kinematical viscosity

Index trubice	Cross-section	l	v	R[1]	□
	m^2	m	m/s	$Pa.s/m^3$	$m^2.s^{-1}$
1-20	0.0010	0.5200	800	4.8E+09	7
41-60	0.0015	0.2000	1300	0	25
82-101	0.0020	0.0700	1299	0	9
61	0.0007	0.0622	1300	1.4E+08	21
62	0.0023	0.1260	1300	0	21
63	0.0039	0.1290	1300	0	21
64	0.0055	0.1310	1300	0	21
65	0.0075	0.1330	1300	0	21
66	0.0088	0.1340	1300	0	21
67	0.0099	0.1350	1300	0	21
68	0.0113	0.1360	1300	0	21
69	0.0133	0.1380	1300	0	21
70	0.0150	0.1390	1300	0	21
71	0.0167	0.1400	1300	0	21
72	0.0191	0.1410	1300	0	21
73	0.0206	0.1430	1300	0	21
74	0.0227	0.1440	1300	0	21
75	0.0249	0.1450	1300	0	21
76	0.0266	0.1460	1300	0	21
77	0.0290	0.1470	1300	0	21
78	0.0308	0.1480	1300	0	21
79	0.0327	0.1490	1300	0	21
80	0.0346	0.1500	1300	0	21
81	0.0346	0.0748	1300	0	21
102	0.0707	70.00	1300	0	10
103	0.0962	10.00	1300	0	15
104	0.3320	35.00	1300	0	15
105	0.3320	35.00	1300	0	10

Table 1. *Model parameters*

Model with dampers

The numerical model with the dampers comes out the previous one. To the vaneless space (VS) were added the dampers, see Fig. 2.

Practically there was placed tubes nr. 106-110, which ended by nodes nr. 67-71 with the flow boundary condition. The tubes are length 0,875m and diameter 15mm. The sound velocity value in them is 1400 m/s and the second viscosity value 5 m^2/s.

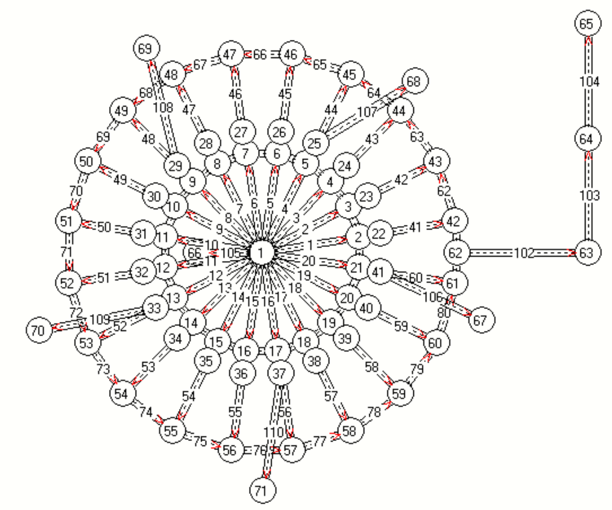


Figure 2: *Mathematical model with dampers*

3. PRESSURE PULSATION MEASUREMENT

Next Figures (Fig. 3 and 4.) show the experimental stand photos. In the VS there were placed 5 pressure pulsation dampers. The pressure measuring was realized in the 5 places in VS and in 4 places in the spiral. Next pressure pulsation values were got from the inlet and outlet of each damper.

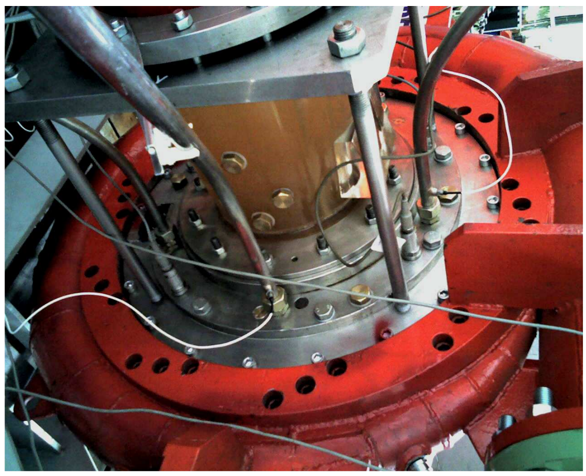


Figure 3.

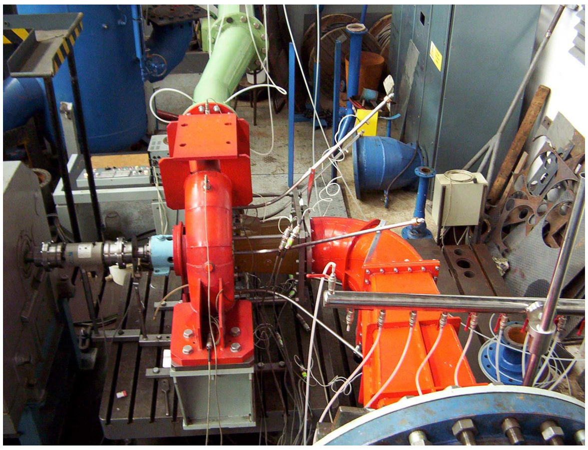
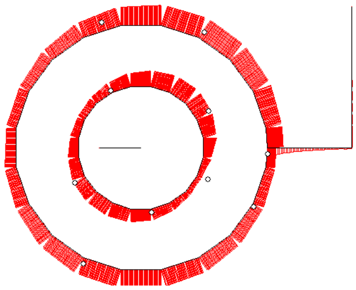


Figure 4.

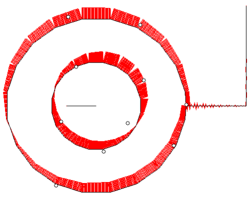
4. MATHEMATICAL SIMULATION RESULTS

Pressure mode shapes for individual phases are illustrated in following figures. Position corresponds to Fig.1, except of pipes 102 and 103, which are shifted to the center of vaneless space to make the picture clearer. Figures show the pressure mode shape in draft tube, vaneless space, spiral casing and penstock. Red color is for computed values, black one for measured values.

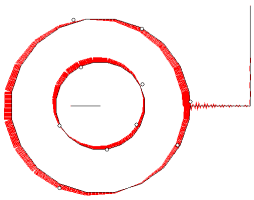
Pump mode of operation



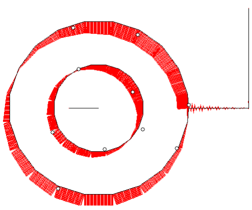
Pressure mode shape



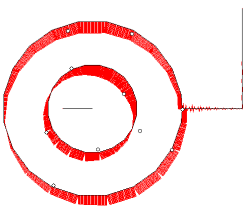
Pressure for $\Phi=0^o$



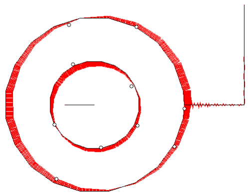
Pressure for $\Phi=60^o$



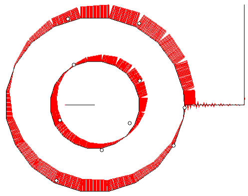
Pressure for $\Phi=120^o$



Pressure for $\Phi=180^o$

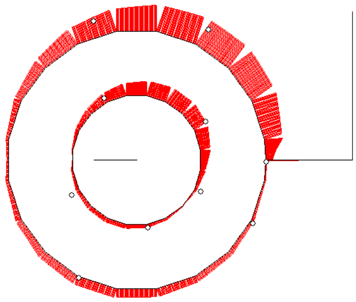


Pressure for $\Phi=240^o$

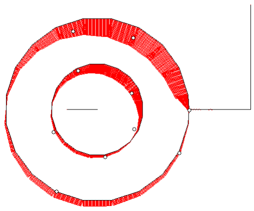


Pressure for $\Phi=300^o$

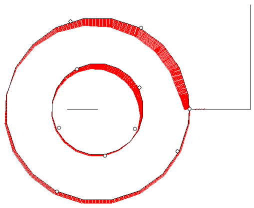
Turbine mode of operation



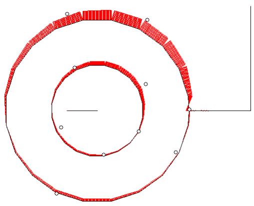
Pressure mode shape



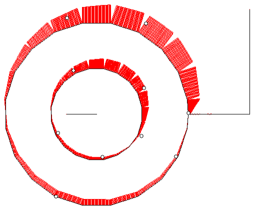
Pressure for $\Phi=0^o$



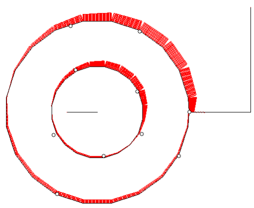
Pressure for $\Phi=60^o$



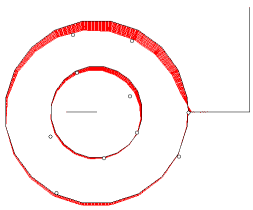
Pressure for $\Phi=120^o$



Pressure for $\Phi=180^o$



Pressure for $\Phi=240^o$



Pressure for $\Phi=300^o$

Following graphs show the pressure wave shapes in the spiral. The angle Φ is measured from the nose of the spiral down the spiral cross section increasing.

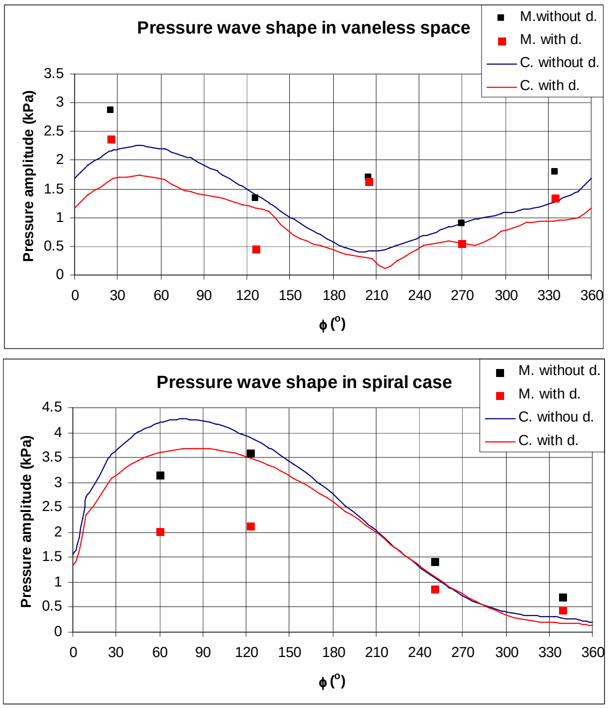


Figure 5. *Pressure wave shape in turbine condition*

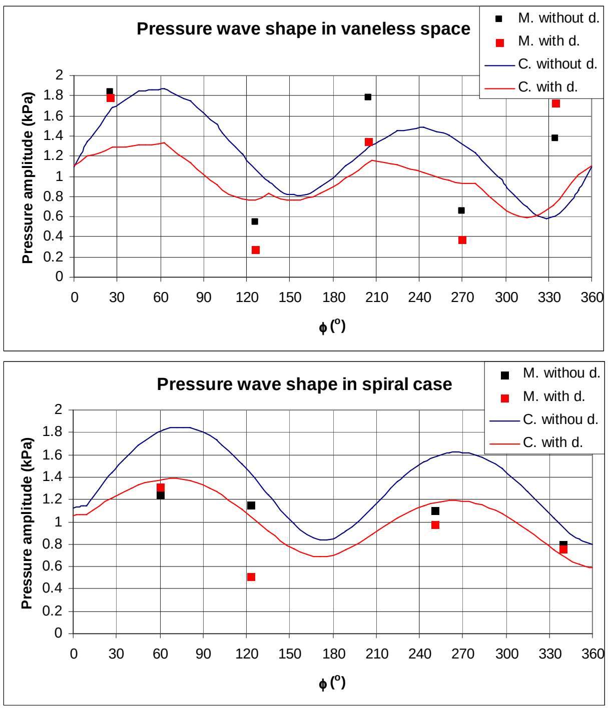


Figure 6. *Pressure wave shape in pump condition*

5. CONCLUSION

From the mathematical simulation and experimental results it is possible to prepare following table. There are listed the average pressure pulsations got from the simulation and experiment.

First four lines are split into the vaneless space (VS) and spiral space. In the last two lines there are calculations of the average pulsation for the whole inner space of turbine.

	Without d.	With d.	Damp.
VS - m. simulation	1.244	0.974	0.783
VS - experiment	1.242	1.098	0.884
Spiral- m. simulation	1.333	1.023	0.767
Spiral- experiment	1.074	0.890	0.829
Mathem. simulation	1.289	0.998	0.775
Experiment	1.158	0.994	0.859

Table 2. *Average pressure pulsations from the experimental and mathematical simulation results*

It may be completed that the dampers usage decreases the pressure pulsations value to the 80% of the primary one.

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6. ACKNOWLEDGEMENT

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7. REFERENCES

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