XX Polish Fluid Mechanics Conference,
Gliwice, 17-20 September 2012

OUTLINE OF THE FORMED SUCTION INTAKE DESIGN METHOD FOR AXIAL-FLOW PUMPS WITH THE VERTICAL AXIS

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Abstract

The article presents a concept of the formed suction intake design method algorithm for vertical axial-flow pumps.

Input data for design of formed suction intakes according to the proposed algorithm are flow parameters of the pump nominal work point:

- HN – nominal head of the pump,
- QN – nominal flow rate.

On the basis of these parameters, the pump selection is made from the catalogue, in which are given the geometrical parameters substantial for its' construction, including a diameter of an inlet. Most often, the inlet diameter of a pump is equal to the outlet diameter of the formed suction intake. Other dimensions of the formed suction intake are based on the diameter of its outlet according to the ANSI 9.8-1988 standard. Afterwards on the basis of this geometry and the nominal rate of delivery QN, numerical computations of the steady flow are carried out.

Next stage of computations involves the geometric parameter optimization of the formed suction intake using one of the chosen design optimization methods. Objective functions in the chosen multiobjective optimization method are closely related with the two flow acceptance criteria given in the ANSI 9.8-1998 standard:

- minimal possible liquid rotation angle in the pump inlet cross-section (standard recommends less than 5˚)
- minimal possible non-uniformity of the velocity profile in the arbitrary point of the pump inlet cross-section to the average velocity determined as the quotient of a flow rate and the cross-sectional area of the pump inlet (standard recommends the acceptable non-uniformity limit up to 10%).

Key words: suction intake, multiobjective optimization

INTRODUCTION

Formed suction intake is a final element of inlet channels in pumps with a vertical axis (Fig. 1). Most often these pumps are mixed-flow pumps or axial-flow pumps characterized by huge capacities (over 15000 m^3/h) and quite low heads. In formed suction intakes there occurs a change of the water flow direction from horizontal to vertical. Such a radical change of the water flow direction generates inconvenient hydraulic phenomena in the formed suction intake.

In the Figure 1 there is shown the scheme of inflow channels to the cooling water pump.

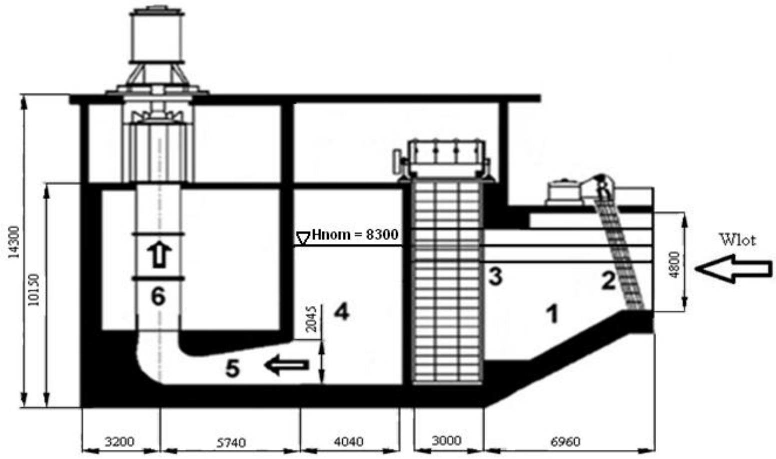

Fig. 1 Real facility – system of the inflow channels

The real pumping station facility (Fig. 1) consists of: the screen chamber (1), where are the trash screens (2) used to roughly purify the water supply flowing in from the high-water source, (3) the rotary screen which task is to thorough purify the water from a pollution, (4) the open wet well, formed suction intake (5) and the cooling water pumps (6).

According to the standard the outflow of the water from the formed suction intake should fulfil the following conditions:

- averaged in time of 10 min, the angle of fluid swirl in the pump inlet cross-section denoted as Θ should fulfill the condition of $\Theta \leq 5°$; there is allowed a momentary deviation (up to 30 seconds) $\Theta \approx 7°$;
- non-uniformity of the velocity profile in relation to the average value from the measurement surface area less than 10% in every point of the Pitot probe measurement.
- fluctuations of the velocity in time, in a given point of the probe measurement, less than 10% in relation to the averaged in time duration of this point measurement.

Limitation or disposal of the water swirl angle, immediately upstream the pump inlet, which measure is a value of the absolute circumferential velocity component c_u can eliminate fluctuations of the pump capacity (Fig, 2).

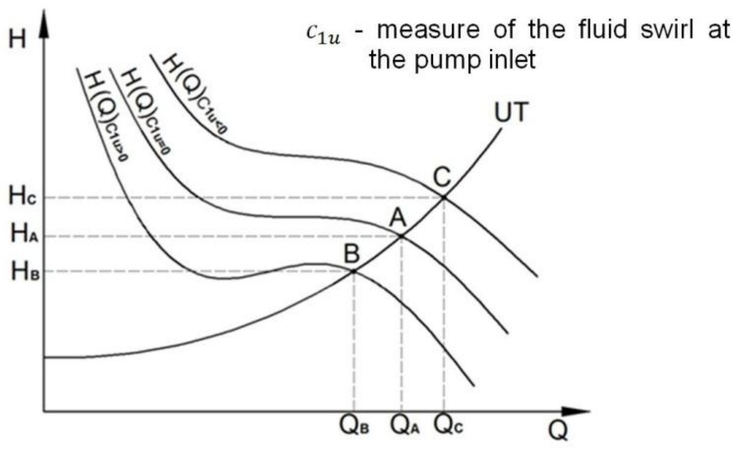

Fig..2 Characteristic curve of the pump flow H(Q)
and characteristics of the cooling water system UT

Realization of permissible by the standard non-uniformities of the velocity profile and velocity fluctuations can improve as well the capacity as the dynamic state of the pump.

In the available literature, there is lack of publications relating to design methods of formed suction intakes, which would control at the stage of velocity non-uniformities computations and fluid swirls at the pump inlet.

In publications relating to the liquid inflow in mixed-flow and axial-flow pumps with vertical axis, there are given only the main dimensions of formed suction intakes in relation to the pump inlet diameter.

In the following figures there are shown the dimensioned outlines of formed suction intakes proposed by the standard ANSI 9.8-1988, Stępniewski, catalogs WFP. They were compared to suction intakes made for Pątnów, Łagisza i Bełchatów power plants.

In these figures were marked:

1. Object – Suction intake which was made and working,
2. Catalog WFP – proposals of the Warsaw Pump Factory,
3. St A i St B – two proposals of dimensioning given in Stępniewski book,
4. Standard – recommended proposals by the standard ANSI/HI 9.8-1998. American National Standard for Pump Intake Design.

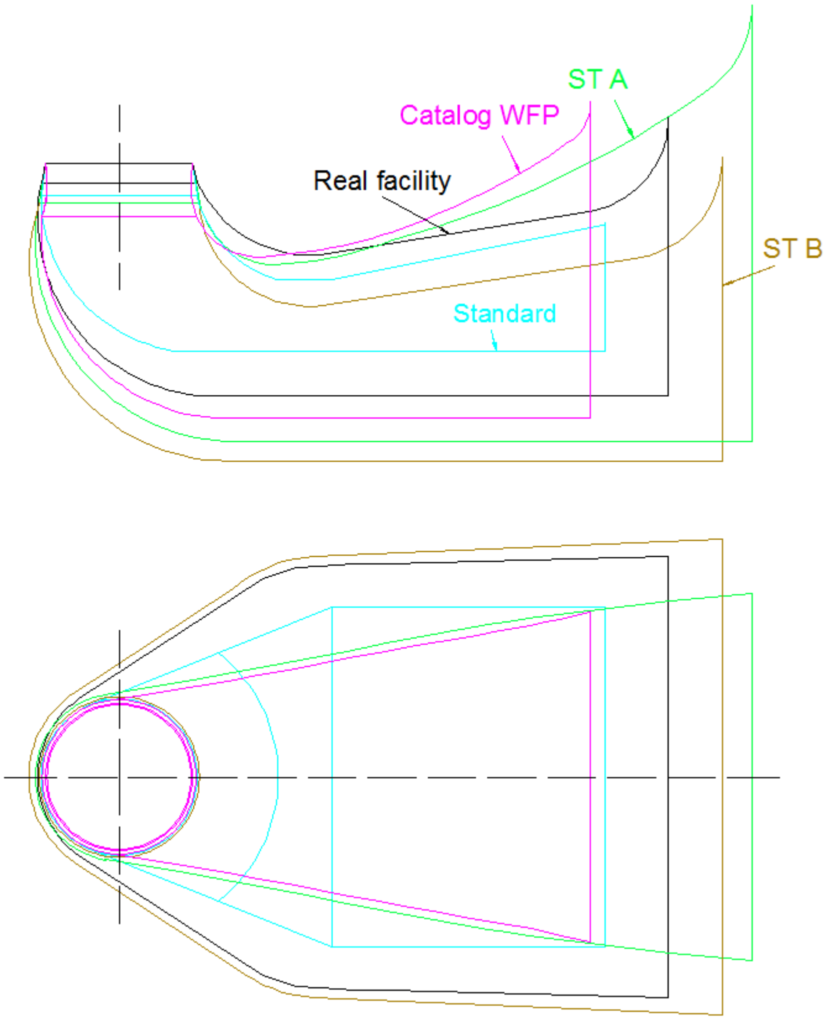

Fig. 3 Meridional contours (a) and longitudinal (b) of suction intakes.
Comparison to the suction intake in the 200MW unit in Pątnów II Power Plant.

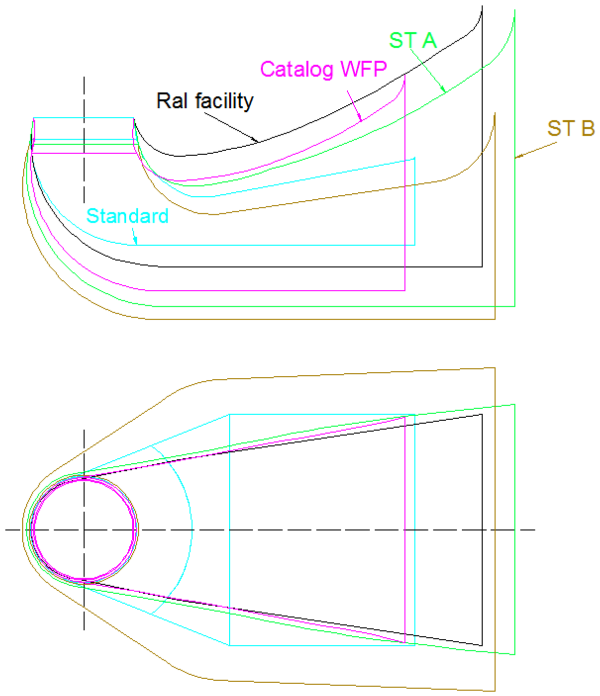

Fig. 4 Meridional contours (a) and longitudinal (b) of suction intakes.
Comparison to the suction intake in the 360MW unit in Bełchatów Power Plant.

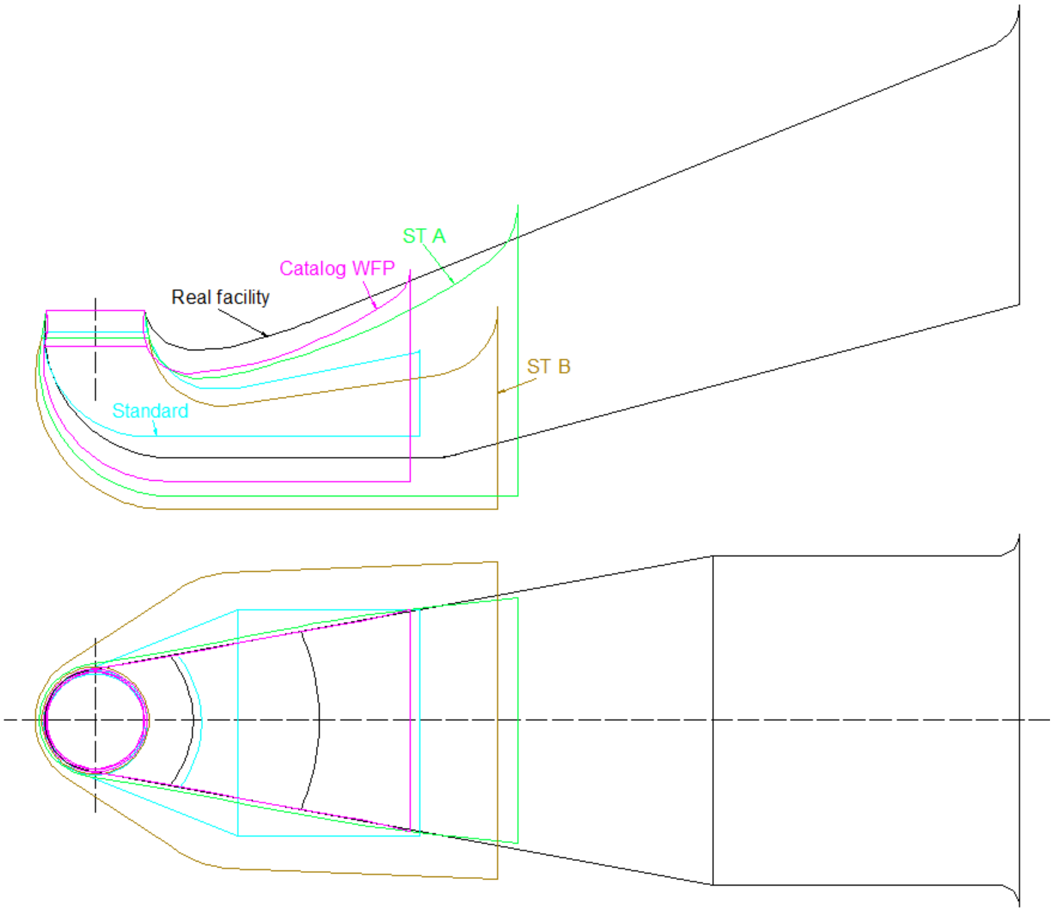

Fig. 5 Meridional contours (a) and longitudinal (b) of suction intakes.
Comparison to the suction intake in the 460MW unit in Łagisza Power Plant.

In the Fig. 6 there were shown main dimensions of the formed suction intake and the proposed in the literature dimensioning, which was shown in the table T-1. Values of geometrical parameters (Fig. 6) of formed suction intakes shown in Fig. 3, Fig. 4, Fig. 5 were set up in the table T-2 (dimensions in cm). Absolute difference (line no 4, 7, 10, 13, 18, 21, 24, 27, 32, 35, 38, 41) is defined as the dimension difference proposed in the literature (line no 3, 6, 9, 12, 17, 20, 23, 26, 31, 34, 37, 40) and the real facility (line no 2, 16, 30). Percent difference of dimensions is an absolute difference in relation to the recommended dimension by the literature, multiplied by 100%.

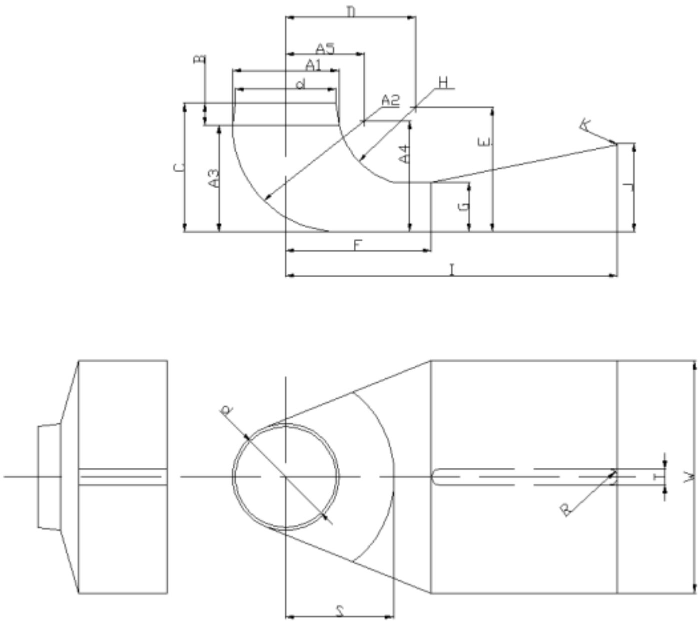

Fig. 6 Main dimensions of the formed suction intake

Dimensional proportions according to the literature Table *T-1*

		A1	A2	A3	A4	A5	B	C	D	E	F	G	H	I	J	K	S	R	T	W
Standard [1]	d	1.06d	1.06d	1.06d	1.06d	0.5d	0.22d	1.28d	1.29d	1.24d	1.45d	0.49d	0.78d	3.3d	0.88d	0.02d	1.08d	0.08d	0.16d	2.31d
ST A [8]		1,09d	1,36d	1,62d	1,36d	0,79d	0,27d	1,89d	1,07d	1,43d	1,05d	1,2d	0,52d	4,3d	2,97d	0,7d	others	lack	lack	2,5d
ST B [8]		1,09d	1,32d	1,75d	1,34d	0,73d	0,27d	2,02d	1,29d	1,8d	1,32d	1,05d	0,75d	4,1d	2,06d	0,7d	others	BD	BD	3,23d
Catalog WFP [7]		1,046d	1,3d	1,37d	1,26d	0,73d	0,36d	1,73d	0,95d	1,57d	0,96d	1,09d	0,47d	3,27d	2,15d	0,33d	others	others	others	2,25d

Setting-up of geometrical parameters of suction intakes shown in Fig. 3, Fig. 4, Fig. 5 Table *T-2*

Lp.																					
1	Pątnów																				
2	Real facility	153	160	185	225,5	256,8	185,8	20	245,53	183,6	254,56	184,57	145,88	107,6	554,07	261	85,17	others	brak	brak	459,3
3	Standard	153	162,18	162,18	162,18	162,18	76,5	33,66	195,84	197,37	189,72	221,85	74,97	119,34	504,9	134,64	3,06	165,24	12,24	24,48	353,43
4	Absolute difference	0	2,18	-22,82	-63,32	-94,62	-109,3	13,66	-49,69	13,77	-64,84	37,28	-70,91	11,74	-49,17	-126,36	-82,11	---	---	---	-105,87
5	Percentage	0	1,34	14,07	39,04	58,34	142,88	40,58	25,37	6,98	34,18	16,80	94,58	9,84	9,74	93,85	2683,33	---	---	---	29,96
6	ST A	153	166,77	208,08	247,86	208,08	120,87	41,31	289,17	163,71	218,79	160,65	183,6	79,56	657,9	454,41	107,1	others	lack	lack	382,5
7	Absolute difference	0	6,77	23,08	22,36	-48,72	-64,93	21,31	43,64	-19,89	-35,77	-23,92	37,72	-28,04	103,83	193,41	21,93	---	---	---	-76,8
8	Percentage	0	4,06	11,09	9,02	23,41	53,72	51,59	15,09	12,15	16,35	14,89	20,54	35,24	15,78	42,56	20,48	---	---	---	20,08
9	ST B	153	166,77	201,96	267,75	205,02	111,69	41,31	309,06	197,37	275,40	201,96	160,65	114,75	627,30	315,18	107,10	others	BD	BD	494,19
10	Absolute difference	0	6,77	16,96	42,25	-51,78	-74,11	21,31	63,53	13,77	20,84	17,39	14,77	7,15	73,23	54,18	21,93	---	---	---	34,89
11	Percentage	0	4,06	8,40	15,78	25,26	66,35	51,59	20,56	6,98	7,57	8,61	9,19	6,23	11,67	17,19	20,48	---	---	---	7,06
12	Catalog WFP	153	160,00	198,90	209,61	192,78	111,69	55,00	264,69	145,35	240,21	146,88	166,77	71,91	500,00	328,95	50,49	others	others	others	344,25
13	Absolute difference	0	0,00	13,90	-15,89	-64,02	-74,11	35,00	19,16	-38,25	-14,35	-37,69	20,89	-35,69	-54,07	67,95	-34,68	---	---	---	-115,05
14	Percentage	0	0,00	6,99	7,58	33,21	66,35	63,64	7,24	26,32	5,97	25,66	12,53	49,63	10,81	20,66	68,69	---	---	---	33,42

Lp.																					
15	Bełchatów 360																				
16	Real facility	130	130	164,2	0	204	124,3	0	194,5	127	204	127	144	62	516	339,64	48	127	lack	lack	300
17	Standard	130	137,8	137,8	137,8	137,8	65	28,6	166,4	167,7	161,2	188,5	63,7	101,4	429	114,4	2,6	140,4	10,4	20,8	300,3
18	Absolute difference	0	7,8	-26,4	137,8	-66,2	-59,3	28,6	-28,1	40,7	-42,8	61,5	-80,3	39,4	-87	-225,24	-45,4	13,4	---	---	0,3
19	Percentage	0	5,66	19,16	100,00	48,04	91,23	100,00	16,89	24,27	26,55	32,63	126,06	38,86	20,28	196,89	1746,15	9,54	---	---	0,10
20	ST A	130	141,7	176,8	210,6	176,8	102,7	35,1	245,7	139,1	185,9	136,5	156	67,6	559	386,1	91	others	others	others	325
21	Absolute difference	0	11,7	12,6	210,6	-27,2	-21,6	35,1	51,2	12,1	-18,1	9,5	12	5,6	43	46,46	43	---	---	---	25
22	Percentage	0	8,26	7,13	100,00	15,38	21,03	100,00	20,84	8,70	9,74	6,96	7,69	8,28	7,69	12,03	47,25	---	---	---	7,69
23	ST B	130	141,70	171,60	227,50	174,20	94,90	35,10	262,60	167,70	234,00	171,60	136,50	97,50	533,00	267,80	91,00	others	BD	BD	419,90
24	Absolute difference	0	11,70	7,40	227,50	-29,80	-29,40	35,10	68,10	40,70	30,00	44,60	-7,50	35,50	17,00	-71,84	43,00	---	---	---	119,90
25	Percentage	0	8,26	4,31	100,00	17,11	30,98	100,00	25,93	24,27	12,82	25,99	5,49	36,41	3,19	26,83	47,25	---	---	---	28,55
26	Catalog WFP	130	135,95	169,00	178,10	163,80	94,90	55,00	224,90	123,50	204,10	124,80	141,70	61,10	424,84	279,50	42,90	others	others	others	292,50
27	Absolute difference	0	5,95	4,80	178,10	-40,20	-29,40	55,00	30,40	-3,50	0,10	-2,20	-2,30	-0,90	-91,16	-60,14	-5,10	---	---	---	-7,50
28	Percentage	0	4,38	2,84	100,00	24,54	30,98	100,00	13,52	2,83	0,05	1,76	1,62	1,47	21,46	21,52	11,89	---	---	---	2,56

Lp.																					
29	Łagisza																				
30	Real facility	140	140	182	210	225,8	139,22	0	210	139,2	225,8	139,2	154,8	71	1319,5	426,1	400	139,2	lack	lack	265
31	Standard	140	148,4	148,4	148,4	148,4	70	30,8	179,2	180,6	173,6	203	68,6	109,2	462	123,2	2,8	151,2	11,2	22,4	323,4
32	Absolute difference	0	8,4	-33,6	-61,6	-77,4	-69,22	30,8	-30,8	41,4	-52,2	63,8	-86,2	38,2	-857,5	-302,9	-397,2	12	---	---	58,4
33	Percentage	0	5,66	22,64	41,51	52,16	98,89	100,00	17,19	22,92	30,07	31,43	125,66	34,98	185,61	245,86	14185,71	7,94	---	---	18,06
34	ST A	140	152,6	190,4	226,8	190,4	110,6	37,8	264,6	149,8	200,2	147	168	72,8	602	415,8	98	others	others	others	350
35	Absolute difference	0	12,6	8,4	16,8	-35,4	-28,62	37,8	54,6	10,6	-25,6	7,8	13,2	1,8	-717,5	-10,3	-302	---	---	---	85
36	Percentage	0	8,26	4,41	7,41	18,59	25,88	100,00	20,63	7,08	12,79	5,31	7,86	2,47	119,19	2,48	308,16	---	---	---	24,29
37	ST B	140	152,60	184,80	245,00	187,60	102,20	37,80	282,80	180,60	252,00	184,80	147,00	105,00	574,00	288,40	98,00	others	BD	BD	452,20
38	Absolute difference	0	12,60	2,80	35,00	-38,20	-37,02	37,80	72,80	41,40	26,20	45,60	-7,80	34,00	-745,50	-137,70	-302,00	---	---	---	187,20
39	Percentage	0	8,26	1,52	14,29	20,36	36,22	100,00	25,74	22,92	10,40	24,68	5,31	32,38	129,88	47,75	308,16	---	---	---	41,40
40	Catalog WFP	140	146,41	182,00	191,80	176,40	102,20	55,00	242,20	133,00	219,80	134,40	152,60	65,80	457,52	301,00	46,20	others	others	others	315,00
41	Absolute difference	0	6,41	0,00	-18,20	-49,40	-37,02	55,00	32,20	-6,20	-6,00	-4,80	-2,20	-5,20	-861,98	-125,10	-353,80	---	---	---	50,00
42	Percentage	0	4,38	0,00	9,49	28,00	36,22	100,00	13,29	4,66	2,73	3,57	1,44	7,90	188,41	41,56	765,80	---	---	---	15,87

others - others construction solution
BD - lack of data about the costruction solution
lack - lack of the construction element

Differences between geometrical parameters of formed suction intakes proposed by different sources (T-1, T-2) and lack of publications (in the available literature) relating to formed suction intakes design methods justified undertaking the work to elaborate the coherent design method of the formed suction intake.

The elaborated method should enable the design of formed suction intakes to implement the required objective functions.

Due to this fact, the design procedure of optimal suction intakes is using among others, results of the numerical flow calculus and applies construction optimization methods in order to search for the best solution in the aspect of implementation of required objective functions.

DSIGN PROCEDURE OF OPTIMAL FORMED SUCTION INTAKES

Below, there were discussed connections and dependences used in the design method algorithm of optimal suction intakes.

The input data for the formed suction intake design is required by the cooling water system, flow parameters of the nominal point of the pump H_N – nominal head, Q_N – nominal capacity.

Rotations of huge axial-flow and mixed-flow pumps hold in limits of n=300-500 rpm. Using this scope, there is done a velocity choice. Lower rotations cause that the pump construction is characterized by a larger size, what has an influence on the pump prize. Limitation for the higher number rotations is a cavitation phenomena. For the required flow parameters H_N, Q_N and assumed rotations, there is determined a specific speed from the following formula Eq. 1.

$$n_{sq} = \frac{n\sqrt{Q_N}}{(H_N)^{3/4}} \qquad \text{Eq. 1}$$

In pump catalogs, besides the flow-energetic parameters: H_N, Q_N, η_N (nominal efficiency), NPSH (required net positive suction head), engine power, size dimensions of the pump aggregate, there is also given a minimal dynamic water inflow head h_{mim} (Fig. 7).

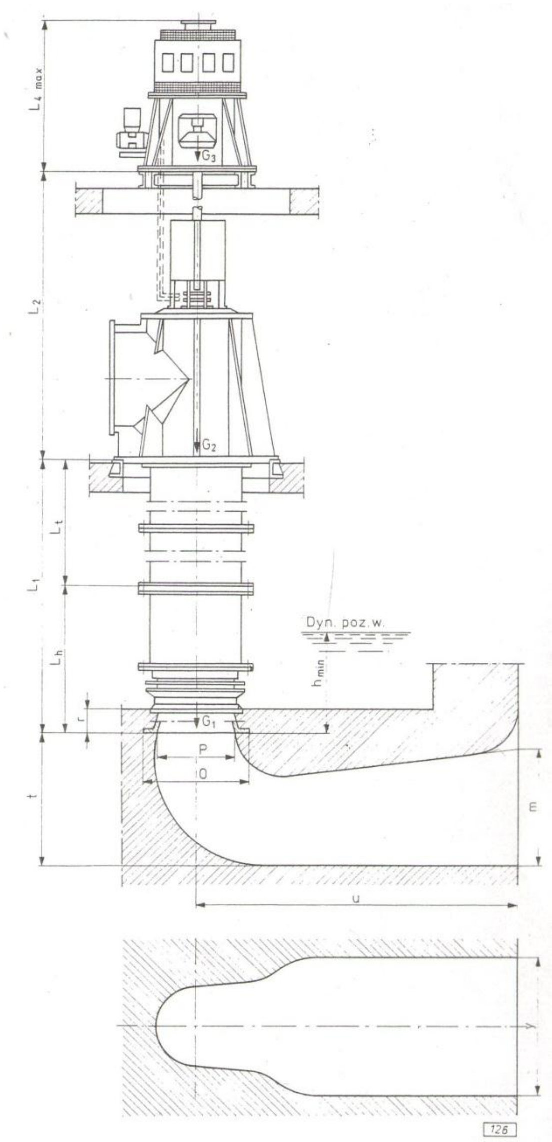

Fig. 7 Scheme of the pump casing with vertical axis

For the chosen dimensioning proportions of suction intakes, nominal pump capacity (Q_N) and minimal inflow head h_{mim} there are carried out numerical computations of the three-dimensional flow.

In the elaborated method algorithm, in the numerical calculus of steady flow liquid parameters in the formed suction intake, the proposal is to use the Ansys software (chapter 3). The decision to choose the program was made due to verification of their values with measurements results done for the studied variant of the suction intake in the Turbomachinery Institute of Technical University of Łódź.

Results of numerical computations of the flow velocity in designed suction intakes are going to be used to determine the consecutive values of objective functions.

Before the start of the shape optimization and solving N-S equations, it is necessary to make a mathematical description of the suction intake walls geometry and a method of the modification, and secondly to develop a creation method of the computational mesh for every acceptable geometry modification. A desirable element (yet not necessary) is also a graphical representation of the shape changes for a process control which aim is to, for instance omit "big mistakes" unforeseen by the computational model.

For the iteration optimization process to be effective, the decision variables describing a shape and size of the suction intake should automatically modify the geometry.

Objective functions according to the standard are going to be:

- swirl angle of the liquid before the impeller eye,
- non-uniformities of the velocity profile at the impeller eye.

In the Fig. 8 there is shown an algorithm of the optimal suction intake design method.

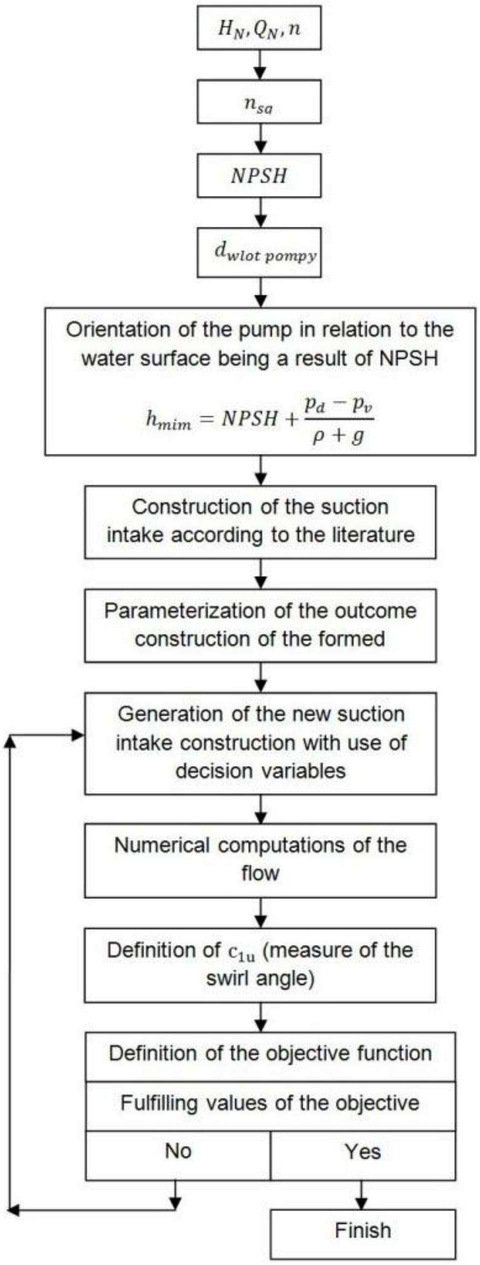

Fig. 8 Design method algorithm

Due to the key meaning of the developed design method of the flow numerical computations of the formed suction intake, they were broadly described (chapter “NUMERICAL COMPUTATIONS OF STEADY FLOWS IN THE SUCTION INTAKE”) in the aspect of the objective function in the standard.

NUMERICAL COMPUTATIONS OF STEADY FLOWS IN THE SUCTION INTAKE

Scheme of numerical computations

Numerical computations of the flow in the method are proposed to be carried out with use of the Ansys 13.0 software. This software is used in numerical computations of the flow in suction intakes, which results were placed in *Badania modelowe kanału ssącego pompy wody chłodzącej 180P19 na stanowisku nr 8 dla bloku A 460MW w Elektrowni Pątnów,* raport z prac etapu I I II.

Scheme of the numerical computation algorithm assumed for steady flow calculus was shown in the Fig. 9.

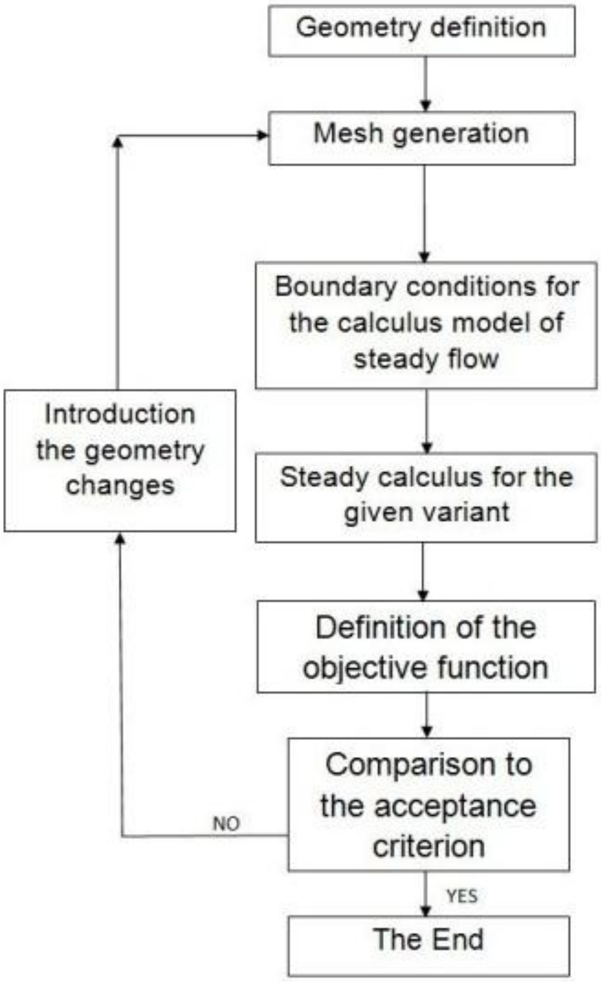

Fig. 9 Scheme of the algorithm of steady flow numerical computations

Numerical computations required:

- modeling of the geometry and the computational mesh generation,
- adoptions of the boundary conditions.

Geometry of channels and the computational mesh

To model the geometry and generate the computational mesh for the analyzed variants of the constructions of suction chambers, there is used a software ANSYS CFX. In the Fig. 10 there is shown an example of geometry and the computational mesh of the inflow channels for the example of the suction intake construction variant.

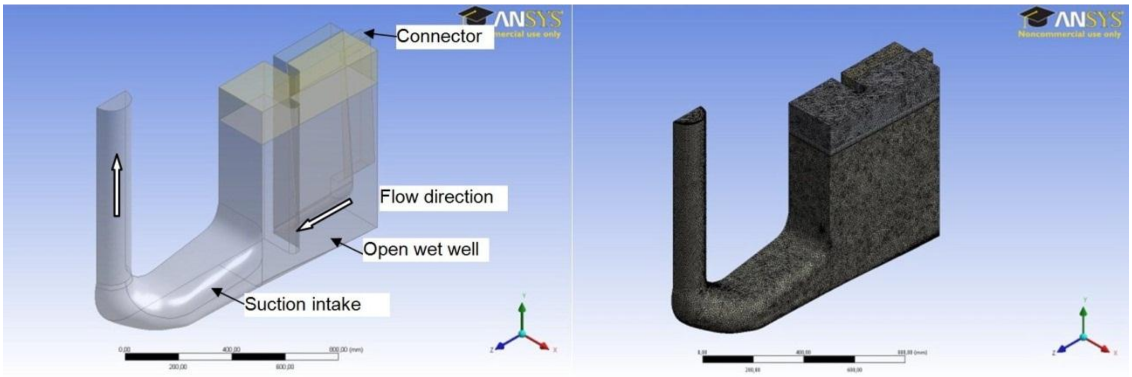

Fig. 10 Geometry and computational mesh for the connector, open wet well and the suction intake

In the Fig. 10 were also marked the flow direction of the liquid throug the above mentioned channels.

Due to the symmetry in relation to the flow direction in the suction intake, open wet well and the connector, there were generated computational meshes for a half of the intake geometry for purpose of computations. The adopted method for the mesh generation eliminated differences of meshes for the both sides of the symmetry plane of intakes.

Boundary conditions

For numerical computations of flows in the suction intake there were assumed outflow parameters from the connector the inlet channels.

In computations of the flow parameters at the outlet of the connector there were assumed the following boundary conditions:

- inlet to the inflow channels – mass flow, dependent on the studied variant of the geometry and flow parameters of the liquid in intakes,
- outlet of the connector – opening pressure and dimensions, assumed value of the pressure 0 [Pa],
- turbulence intensity at the level of 5% (when $I = 10$) according to the formula:

$$I = \frac{\mu_t}{\mu_d} \quad \text{Eq. 2}$$

where: μ_t – turbulent viscosity,
μ_d – dynamic viscosity

- zero gradient of the pressure in the direction of the main flow (this condition is assumed internally by the ANSYS-CFX preprocessor).

In order to carry out computations in inflow channels, it is necessary to assume additional settings:

- walls hydraulically smooth with a slowdown of the agent at the wall,
- there was assumed a SST turbulence model
- logarithmic distribution of the velocity at the wall, so called wall function
- constant agent temperature,
- automatic timestep change.

For computations in the suction intake there is proposed the following boundary conditions:

- inlet – velocity profile distribution from the outlet of the connector
- outlet – static pressure,

- turbulence intensity computed at the outlet of the connector,

In order to carry out the computations there is necessary to adopt the additional settings:

- hydraulically smooth walls without the lost motion,
- SST turbulence model,
- logarithmic distribution of the velocity at the wall, the so called wall function
- constant temperature of the agent,
- automatic timestep change.

Programme for numerical computations

Programme of numerical computations is strictly connected with definition of the objective function for the each analyzed solution of the suction intake construction.

At the stage of the method development of formed suction intakes there was also taken into account the verification of objective functions adopted according to the standard. Description of the objective function was shown in the chapter next.

EVALUATION OF THE OBJECTIVE FUNCTION

In the proposed method, there were adopted initially the two objective functions according to the standard:

- non-uniformities of the velocity profile at the outlet from the formed suction intake. According to should not exceed 10%,
- average swirl angle of the liquid at the outlet from the suction intake, should not exceed $\Theta = 5^{\circ}$.

Numerical computations of the steady flow in the formed suction intake in the range, necessary for the objective function evaluation, was carried out for the work parameters of the flow system model (made in a scale 1:10 in relation to the real facility Fig. 1), Q_N=24,6 kg/s and the level of the water surface H_N=665 mm.

Non-uniformities of the velocity profile at the outlet of the formed suction intake

Criteria concerning the non-uniformities of the velocity profile according to standard is defined as the ratio of the averaged velocity in the given point of the control surface to the average velocity at the outlet surface of the formed suction intake determined from the continuity equation $(c_{śr})_{rc}$.

$$(c_{śr})_{rc} = \frac{4Q_N}{\pi d^2} \qquad \text{Eq. 3}$$

where: Q_N – nominal capacity of the pump,
d - diameter of the outlet from the formed suction intake.

Points at which the numerical computations respond to points of the Pitot probe measurements.

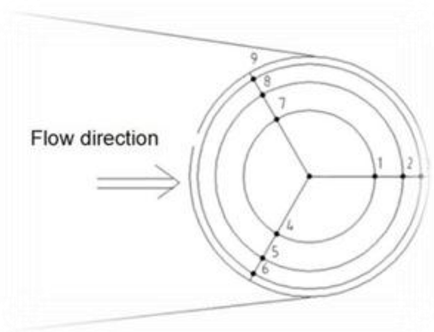

Fig. 11 Points of the Pitot probe measurements

Computed numerically velocities in points of the probe measurement in the analyzed case did not exceed acceptable values (Fig. 12).

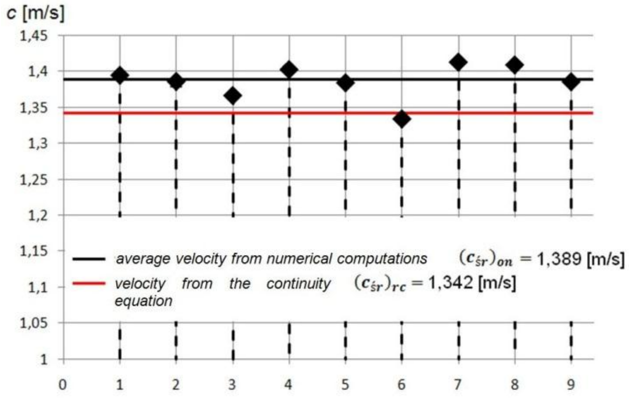

Fig. 12 Averaged values of the velocity obtained from numerical computations

In the Fig. 12 there was also marked, using the black solid line, arithmetic average from velocities computed numerically in points of the Pitot probe measurements.

Whereas velocities measured with the Pitot probe exceed the acceptable values of non-uniformities given in standard. In most of the studied variants of suction intakes in points 6, 9 (Fig. 11) overrun the allowable values amount to over a dozen percent.

An objective of the optimization in the aspect of meeting the requirements standard in range of the velocity profile non-uniformities, will be introduction of construction changes of the suction intake, which will also eliminate in points 6 and 9 (Fig. 11), exceeding of acceptable values.

Swirl angle of the liquid at the outlet of the formed suction intake

Standard allows at the outlet of the formed suction intake, value of the averaged swirl angle $\Theta = 5^{\circ}$.

It also gives a method for its' determination, dimensions and a construction solution for the swirl-meter (Fig. 13, 14) and a definition of the angle Θ Eq. 4.

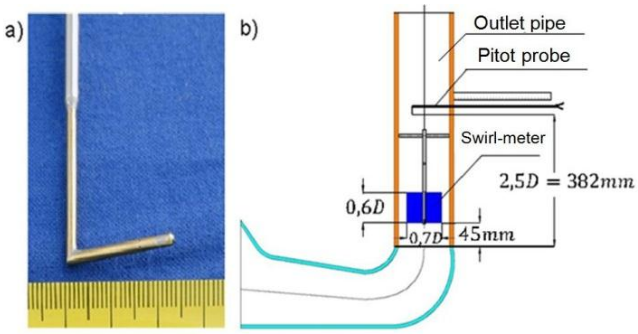

Fig. 13 Scheme of the Pitot probe application and a swirl-meter in the outlet pipe
a) view of the probe b) view of the geometry

Fig. 14 View of the suction intake, open wet well, and the fragment of a measuring piping system (outlet pipe) with installed Pitot probe and a swirl-meter

At the rotation speed of the swirl meter „n", an average liquid swirl angle is equal to according to the formula Eq. 4.

$$\Theta = tan^{-1}\frac{\pi d n}{c_a} \qquad \text{Eq. 4}$$

where: n - rotation speed of the swirl meter,
d - diameter of the pump inlet,
c_a - component of the axial velocity.

The measurement was about counting the full rotations of the swirl meter made in the time of 30 sec.

Graphical illustration of a dependence Eq. 4 was shown in the Fig. 15.

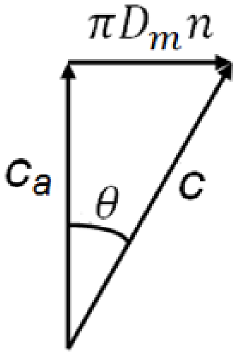

Fig. 15 A velocity triangle in the vicinity of the swirl meter

A run of the swirl angle Θ variation in a time function determined on the basis of measurements Fig. 16.

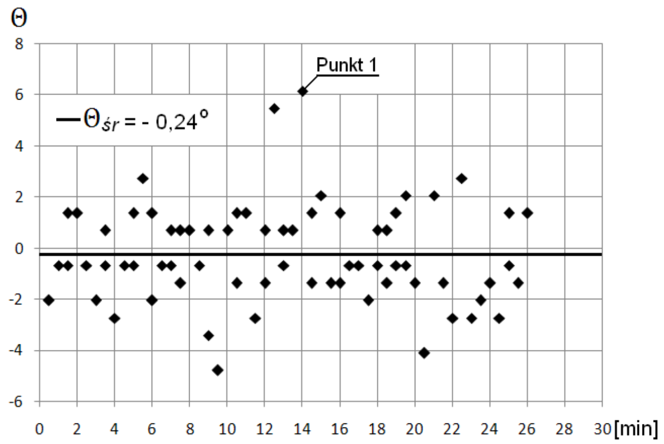

Fig. 16 Change of the swirl angle in the time function.
Collection of points obtained on the basis of measurement of number of rotations of the swirl meter in time of 30 minutes

For every studied variant of suction intakes a level of average values of angle Θ was close to zero, despite the fact that in few measurement points there occurred fluctuations of the angle Θ exceeding the acceptable value of the angle $\Theta = 5^{\circ}$.

Therefore, it was concluded that the proposed by standard criterion concerning the averaged in time angle $\Theta < 5^{\circ}$ does not guarantee an optimal inflow at the in points of the Pitot probe measurements were used to determine the value of angle Θ in these points. Values of computed angles were set up in the table T-3.

Summary of the liquid flow velocity and its' axial components (c_u), radial (c_r) and circumferential (c_a) and swirl angle Θ, for $(h_N)_m (waterlevel\ in\ the\ model\ of\ the\ suction\ inlet\ for\ the\ nominal\ capacity) Q_N$ Table *T-3*

Lp.	c [m/s]	c_u [m/s]	c_r [m/s]	c_o [m/s]	Θ [°]
1	1,419	0,052	0,114	1,413	2,120
2	1,405	0,007	0,062	1,404	0,299
3	1,350	-0,034	0,017	1,350	-1,456
4	1,423	0,023	-0,026	1,422	0,923
5	1,409	-0,069	0,005	1,408	-2,793
6	1,321	-0,127	0,004	1,315	-5,499
7	1,405	0,056	-0,076	1,402	2,296
8	1,383	0,180	-0,041	1,371	7,481
9	1,282	0,262	-0,012	1,255	11,779

Likewise in the case of non-uniformities of the velocity profile, the biggest angles Θ occur in points 6 and 9 of the Pitot probe measurement.

As for the measure of the liquid flow at the outlet of the formed suction intake it is also adopted an averaged value of the circumferential component c_u of the absolute velocity. Such defined swirl remains in a strict relation with the swirl angle. In the Fig. 17 there was shown a distribution of the velocity component at the outlet of the suction intake.

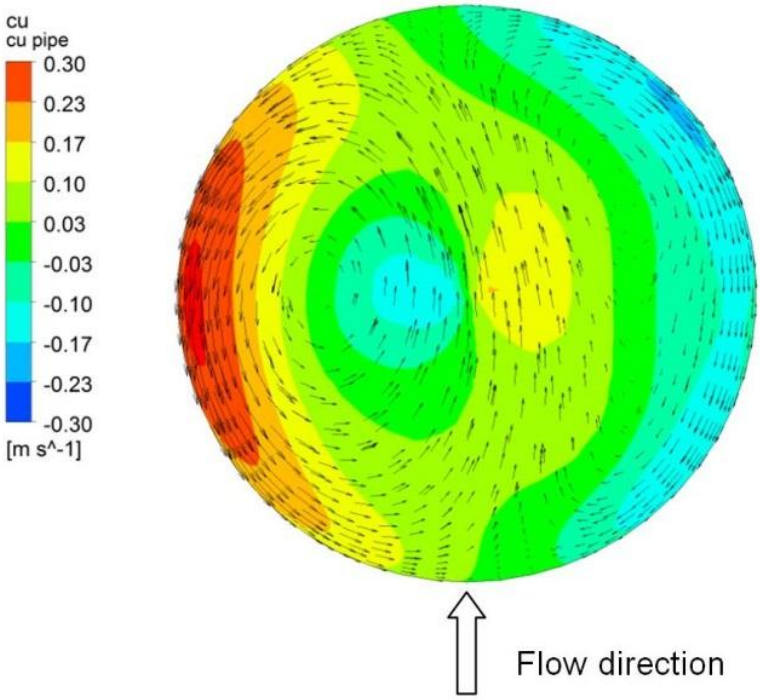

Fig .17 Distribution of the circumferential velocity component

Distribution of the velocity circumferential component c_u (Fig. 17) indicates an occurrence of swirl zones in the whole area of the pump inlet. These swirls cause changes of the liquid angle of incidence at the impeller blades. Because of that there should be determined swirl angles in zones of the most intense swirls, in order to provide an inflow of the liquid at the impeller blades in the range of acceptable incidence angles.

Due to that it is recommended that the criterion of the size evaluation of the swirl is not an averaged angle, yet its' critical value (local) should be less than maximal acceptable angles of incidence of the liquid at the impeller blades.

CONCLUSIONS

These conclusions may be set up in the form of the following points:

1. Introduced design algorithm of optimal formed suction intakes requires further development, in particular in the scope of numerical computations of steady flows and objective functions.
2. On the basis of Fig. 17 illustrating the circumferential component c_u distribution, at which there was imposed a velocity vector field, it can be noticed that the recommended by standard criterion concerning the swirl angle Θ does not guarantee obtaining the irrotational flow at the impeller. According to the authors of the paper, this proposal should

REFERENCES

American National Standard for Pump Intake Design. ANSI/HI 9.8-1998. Hydraulic Institute. 9 Sylvan Way, Parsippany, New Jersey 07054-3802

Błaszczyk A., Kunicki R. (2010): *Koncepcja numerycznego i doświadczalnego badania przepływów nieustalonych w komorach wlotowych pomp.* Zeszyty naukowe Politechniki Łódzkiej Instytutu Maszyn Przepływowych, Cieplne Maszyny Przepływowe – Turbomachinery, Vol. 137, s. 13-22

Błaszczyk A., Najdecki S., Papierski A., Staniszewski J. (2006): *Badania modelowe kanału ssącego pompy wody chłodzącej 180P19 na stanowisku nr 8 dla bloku A 460MW w Elektrowni Pątnów*. Raport z prac etapu I. Arch. IMP-PŁ 1542

Błaszczyk A., Najdecki S., Papierski A., Staniszewski J. (2006): *Badania modelowe kanału ssącego pompy wody chłodzącej 180P19 na stanowisku nr 8 dla bloku A 460MW w Elektrowni Pątnów*. Raport z prac etapu II. Arch. IMP-PŁ 1546

Błaszczyk A., Susik M. (2010): *Koncepcja badań struktury przepływu w komorach wlotowych pomp z uwzględnieniem przepływów ustalonych.* Zeszyty naukowe Politechniki Łódzkiej Instytutu Maszyn Przepływowych, Cieplne Maszyny Przepływowe – Turbomachinery, Vol. 137, s. 23-32

Kunicki R. (2011): *Numeryczne i doświadczalne badania przepływów nieustalonych w komorach wlotowych pomp.* Praca doktorska. Politechnika Łódzka

Pompy przemysłowe Katalog SWW 0871 Tom 1 i 2. (1988). WPM „Wema"

Stępniewski M. (1985): *Pompy wydanie 2 częściowo przerobione.* Wydawnictwa naukowo-techniczne