THE INFLUENCE OF THE INLET ANGLE OVER THE RADIAL IMPELLER GEOMETRY DESIGN APPROACH WITH ANSYS

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Abstract: This paper presents in brief an own application (numerical code) for quick design of the turbo machines impellers. Based on this numerical method, this paper analyses the influence of the blades' angles on the radial impeller geometry from the centrifugal pumps: the influence of the inlet and outlet angles of the blades over the hydraulic channel size, over the number of the blades and over the blades' angular extension. In centrifugal pumps design, a special attention must be given of the impeller inlet and outlet angles. These influences include also the pump efficiency, for 1-2 percent.
The impeller design methods starting from the pump flow, the head, the rotation speed and ranging blades inlet and outlet angles, gives completely the impeller geometry - the suction and discharge diameters of the impeller, the number of blades and the size and shape of the hydraulic channel and estimates the efficiency for centrifugal pumps.
Once the impeller geometry established, the dates were imported in ANSYS code, for graphical design and 3D visualization of the radial impeller, also for the streamlines flowing visualization.

Keywords: centrifugal pump, impeller design, flowing simulation

1. THEORETICAL APPROACH OF THE RADIAL IMPELLER DESIGN

In the actual energetic context, it is necessary to reduce the energy consumption. Hydraulic machines have an important position in the mechanical engineering field, reason to make their work efficient, to redesign these machines both to increase the hydraulic performances and to reduce the energy consumption, also for their automate working.

The author was developed an own numerical application / software for quick design of the radial and mixed impellers of the centrifugal pumps The algorithm used in this application combines different methods of hydrodynamic computation: the finites differences method, Navier Stokes equations in a steady flowing in the impeller, and statistically computation dates from the technical dedicated literature. With this application can be analyzed the hydraulic performances of the radial or diagonal impellers and the influence of each geometric element over the impeller efficiency.

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This paper proposes to study the influence of the blades' angles on the impeller geometry of centrifugal pumps. The impeller design methods starting from the pump flow, the head, the rotating speed and modifying blades inlet angles, gives the impeller geometry, the number of blades, the size of the hydraulic channel and the shape of the blades.

Starting from the flow rate, the heat and the nominal working speed, the specific speeds were determinated with the relations' gives by equations (1).

$$n_s = n\frac{Q^{1/2}}{H^{3/4}}; \tag{1}$$

To estimate, with great precision, the pump efficiency on use an own conception relation (2), based on Anderson's relation [1] and on maximum values of hydraulic efficiency η_h, depending on n_s speed, gave by A.J. Stepanoff, [2, 3], also in [4-7]. Relation (2) is based also on statistically computation dates. This relation was experimentally confirmed on prototype impellers, made in Aversa SA [8].

$$\eta = f(n_{sQ}) \quad ; \quad \eta = \eta_m \eta_v \eta_h$$
$$\eta = ((1+\frac{10.87}{n_s^{\ 5/3}})^{-1} - \frac{1}{1.81 \cdot Q^{0.25}})^{1.1} \tag{2}$$

Applying the finite differences method to define the blade shape with double curvature, on computed the main impeller dimensions and the angular blade extension, that respect the proposed inlet and outlet angles β_1, respectively β_2. Also the number of the blades was calculated [5-8]. Using semi empirical Pfleiderer relation and correction coefficients C_p, the streamlines were designed, first the central one, than the median streamlines (Figure 1), based on constant hydraulic couple and static moment of the central streamline A_1A_2.

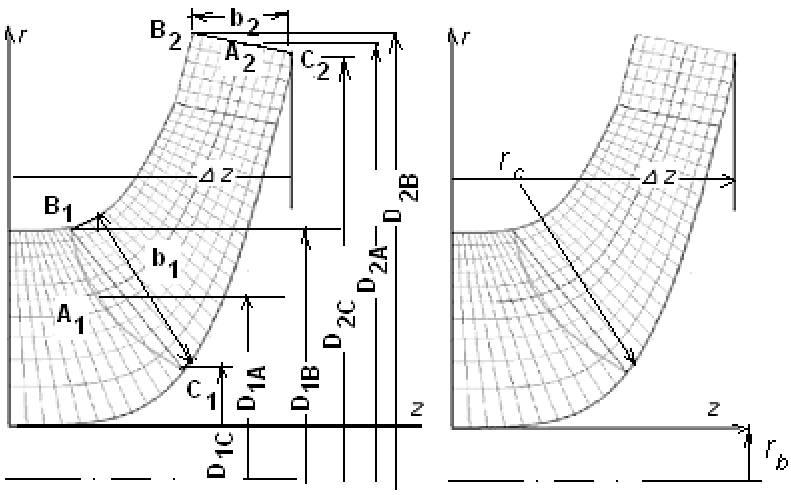


Fig. 1. Main impeller dimensions and streamlines in meridian plane.

$$\psi = (1 \div 1.2)(1+\sin\beta_2)\frac{D_1}{D_2} \quad if\ \frac{D_2}{D_0} \le 1.9 \quad or$$
$$\psi = (0.55 \div 0.68) + 0.6\sin\beta_2 \quad if\ \frac{D_2}{D_0} \ge 1.9. \tag{3}$$

Equations (3) are used to determinate the correction coefficients for pressure gives in relation (4) by Pfleiderer [5].

$$C_p = 2\frac{\psi}{z}\frac{1}{1-(D_1/D_2)^2} \tag{4}$$

To establish the mains dimensions of the radial impeller (r_1, r_2, b_1, b_2, , Δz - blade width in meridian plane) depending of the specific speed n_s, on use relations (5). Then, with different inlet and outlet blades' angles, the flowing channel of the impeller and the number of blades can be sized.

$$\begin{aligned} r_2 &= \left(\frac{n_s}{2.463}+192.894\right)^2 \frac{\sqrt{H}}{n} \\ r_1 &= f(n_s, r_b, r_2) \\ \Delta z &= (D_{2B}-D_0)\left(\frac{n_s}{74}\right)^{1.07} + \frac{b_2}{2\cos\gamma} \\ b_2 &= \phi \ \frac{Q'}{c_{m2}\pi D_2} \\ b_1 &= \Delta z_{max} - f(r_c) \end{aligned} \tag{5}$$

The number of the impeller's blades for clean water is calculated by an iterative method based on relation (6), references [5-8]. There is a close link between the inlet and outlet angles of the blade and the blades number.

$$z = 6.5\frac{D_2+D_1}{D_2-D_1}\sin\left(\frac{\beta_1+\beta_2}{2}\right) \tag{6}$$

Starting from these relations, using also numerical iterative methods to integrate the Navier Stokes equations, we developed an application in TurboPascal (numerical code), dedicated to quick design of the radial and mixed impellers. This own application is summary similar to Cfturbo and Pump Design Code.

The numerical application also gives the shape of the blades with their angular extension and simple or double curvature, for radial or mixed impeller of the centrifugal pumps.

Proposed numerical method offers the possibility to design an impeller for optimal working point, at the best efficiency point BEP or with a minimal net positive suction head [9-11]. For this purpose the inlet angle and the number of the blades have major influence.

Notations:

H – discharge head (m),	Q – fluid flow (m^3/h),
n – rotation speed (rot/min),	n_s –specific speed,
n_{sQ} – kinematics' specific speed,	
β_1 – blade inlet / suction angle,	β_2 – blade outlet/discharge angle,
b_1 – breadth of impeller at inlet,	b_2 – breadth of impeller at outlet,
ψ - pressure coefficient,	C_p - Pfleiderer correction coefficient,
D_0 – inlet impeller diameter (m),	D_1 – inlet blade diameter (m),
D_2 – outlet impeller diameter (m),	D_b – hub impeller diameter (m),
z –number of the blades,	
η - efficiency of the impeller (%),	η_h – hydraulic efficiency,
η_m – mechanical efficiency,	η_v – volumic efficiency,

2. THE INFLUENCE OF THE INLET ANGLE OVER THE RADIAL IMPELLER GEOMETRY

Based on the above relationships and using this dedicated application, the influence of the blade angles over the impeller geometry was highlighted: ranging the values of the suction angles β_1, and keeping constant the discharge blades' angles β_2, it can be sized the flowing channel of the impeller and the number of the blades and their angular extension [12-14].

The following analyze is a case study, developed on the numerical application. Computation was made for flow rate of 5 m^3/h, head equal with 7.5 m and rotation speed equal with 2900 rot/min.

So, for the inlet angles β_1 ranging between 15 to 29 degrees, it can be visualize the inlet breadth of the impeller b_1, important as values, between 11 to 7 mm. In graphical representation from Figure 2, it can see such variation, for the discharge blades' angles β_2 constant, equal with 30 degrees.

For the same variation of the suction angles β_1 ranging between 15 to 29 degrees and β_2 constant, equal with 30 degrees, it was analyzed the breadth of impeller at the discharge diameter, b_2 is calculated between 6 and 6.5 mm, as was graphical represented in Figure 3.

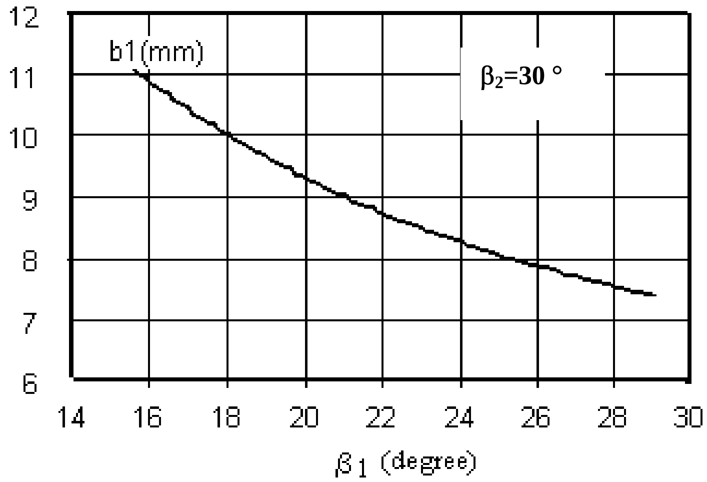


Fig. 2. The breadth of impeller at inlet at different inlet angles β_1.

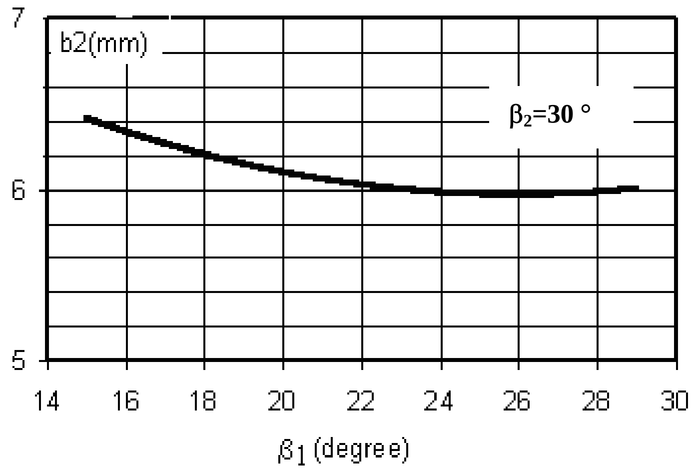
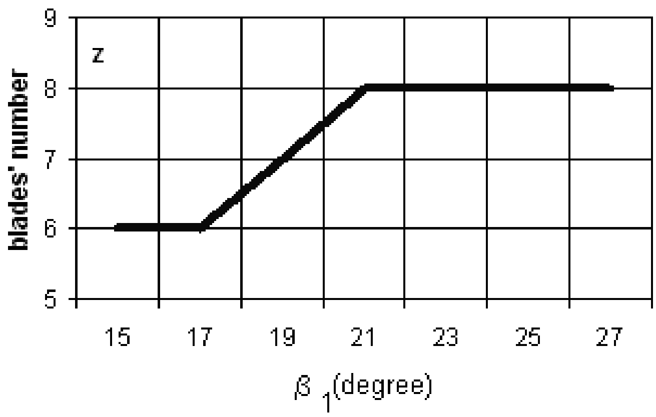


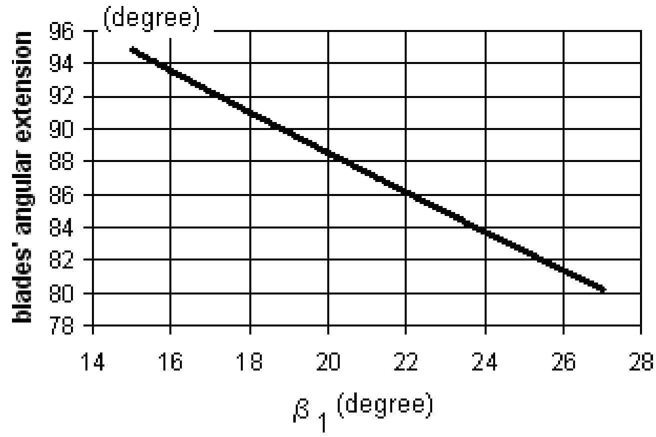
Fig. 3. The breadth of impeller at outlet at different inlet angles β_1.

The variation of the number of the blades with inlet parameters is illustrated in Figure 4.a. The number of the blades increases with the inlet angle increasing. The angular extension of the blades is also illustrated in Figure 4.b and it start from 95 degrees for suction angles β_1 ranging equal with 15 degrees and decrease to 80 degrees for β_1 equal with 29 degrees; β_2 equal with 30 degrees.

Regarding the efficiency of the studied impeller, this is about 58 – 60%, the designed impeller is one of small dimensions.



a)



b)

Fig. 4. a. The number of the blades depending of the inlet angle of the impeller; b. Blades’ angular extension.

3. DESIGN APPROACH WITH ANSYS CODE

Once the impeller geometry established, the dates were imported in ANSYS code, for graphical design, for the visualization of the blades curvature and 3D visualization of the radial impeller, also for the streamlines visualization. The graphical design is used both to verify the correct sizing of the impeller, also to visualize the flowing streamlines [9, 15-17] in the impeller. With dates imported from the previous paragraph, the effect of blades’ inlet angle variation on the shape and curvature blades is presented in Figure 5.

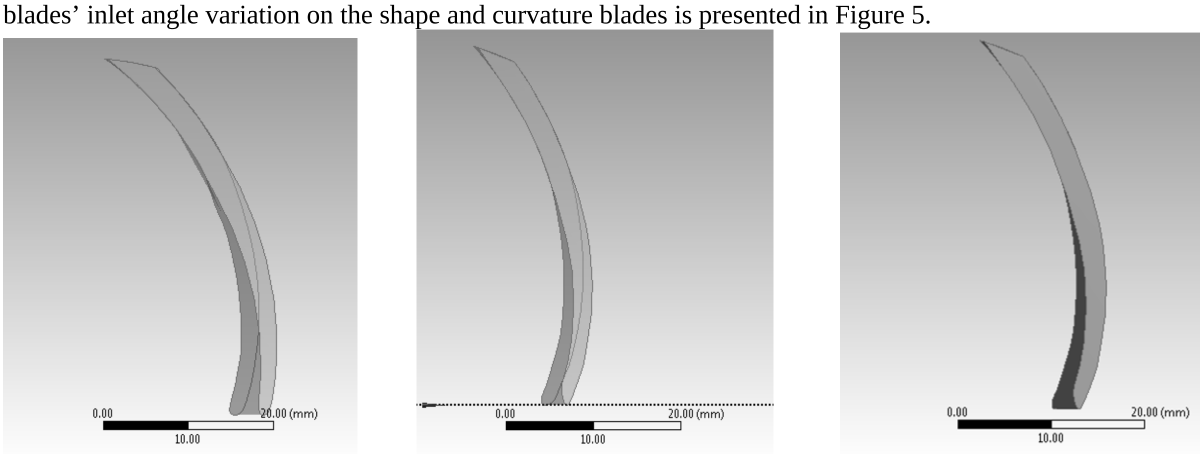


Fig. 5. Blade curvature, 3D geometry modified with suction angles β_1 of 15, 19, 23 degrees.

The three-dimensional radial impellers with six, seven and eight blades are represented in Figure 6.

Using ANSYS code it can visualize the streamlines flowing in one of these impellers - like in Figure 7.

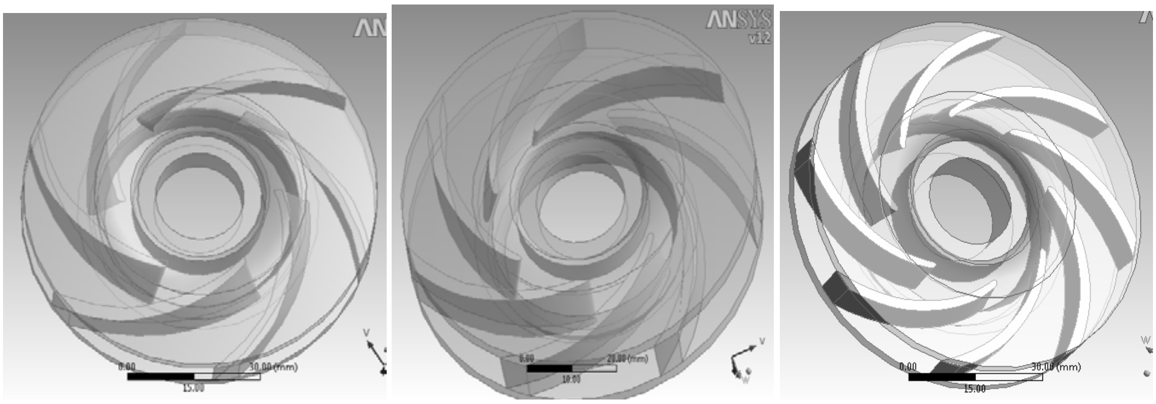


Fig. 6. 3D Visualization of radial impellers with 6, 7, or 8 blades.

Of course the graphical representation could be done with AutoCAD 3D, but using ANSYS code the graphical design is better, it can visualize better continuity of lines, the correct sizing of the blades and discs of the impellers.

Also, it can mesh the impeller, it can be made a finite elements analyze for correct sizing of the blades and impeller, in the purpose to manufacture pieces of minimal weight and minimal moment of inertia.

Also, with ANSYS code it can obtain the spectrum and velocities and pressures distributions in the impeller, subject to be approached in next article.

Using ANSYS code it can visualize the streamlines flowing in one of these impellers – as it can see in Figure 7 that is important both for single stage pumps, also for multistage pumps, also to visualize the relative vortex that influences the pumps efficiency.

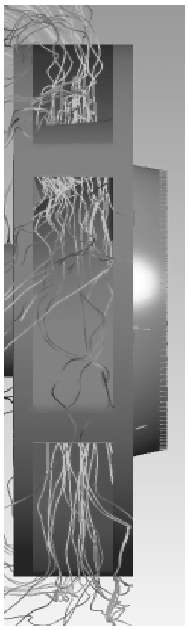


Fig. 7. Visualization of the streamlines in the radial impeller of centrifugal pumps.

4. CONCLUSION

This paper present an own numerical application dedicated to the impellers' design, in brief similar to Cfturbo and Pump Design Code. This application gives the dimensions and the geometry for radial and mixed impellers. This dedicated application including the efficiency relation (2) is original, based on statistically computation dates, and confirmed experimental on prototype impellers, produced in Aversa SA.

Proposed numerical method offers the possibility to design an impeller for optimal working point, at the best efficiency point BEP or with a minimal net positive suction head. For this purpose the inlet angle and the number of the blades have major influence.

Also, this paper analyses the influence of the blades' angles on the radial impeller geometry from the centrifugal pumps: the influence of the inlet angle of the blades over the hydraulic channel size, over the number of the blades and over the angular extension with simple or double curvature of the blades, for radial or mixed impellers of the centrifugal pumps.

It was resumed the design relations and a case study for flow rate of 5 m^3/h, head equal with 7.5 m and rotation speed equal with 2900 rot/min. The inlet angle β_1 was modified, keeping constant the angle β_2.

The influence of the suction angles $\beta_{1,}$ variation and constant discharge blades' angles β_2, on the radial impeller geometry can be so resumed: at the inlet blades' angle increase, increase the number of the blades, the hydraulic channel width (breadth) decreases, the angular extension also decreases. Regarding the impeller efficiency, that varied with 1 – 2 percent.

Fast data transfer and 3D visualization using ANSYS, with the streamlines visualization for fluid flowing in radial impeller of centrifugal pumps, improve the efficient design of these hydraulic machines and illustrate the correct sizing and geometry of the impellers.

In next articles will be analyzed the velocities and pressures distributions in the impellers of turbo-machines, using ANSYS code.

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