CAD TECHNIQUES USED TO OBTAIN THE BLADE SURFACE INTERSECTIONS WITH HORIZONTAL CUTTING PLANES FOR FRANCIS TURBINE RUNNER

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Using CAD techniques for Francis turbine runners design enables an optimization of the blade shape hereby that energetic transfer to be realized with better efficiency then the old classical methods. For manufacturing the runner is necessary to cut the blade with horizontal parallel planes. These sections allow building of the blade step by step.

The classical method for identification of these sections presumes founding the intersection points of these planes with the profiles placed on the stream surfaces. In this way intersecting a stream surface with a plane on obtain maximum two points, one for pressure side and another for suction side of the profile. Therefore the number of points obtained by the intersection with a horizontal cutting plane depends of stream surfaces number. Hereby the extreme area of the blade will result with reduce number of points and leading edge area too. The interpolation of the curves passing through these points will be approximately (great error span).

To have in view these shortcomings of the classical method it was searching for a new possibility to found of these intersections considering that the profiles placed on the stream surfaces are defined by many points (100…200). The network of lines segment which join these points defines the blade surface. Intersecting these line segments with horizontal cutting planes will be obtained maximum possible of points, depending of degree definition of profile boundary, indifferent of the area where intersection is made.

Keywords: CAD techniques, surface intersections, Francis turbine runner.

1. Introduction

Technical and technological progress registered in the last period in hydraulics machinery domain, impose a new tackling in a few design phases. In a first time the actual calculus technique is net superior comparative with the 20…30 years ego, and then grace of that the optimize methods was developed, giving possibility to the designer to analyze in short time more possible variants, to make the corrections depending of results obtained by numerical simulation of flow, results of experimental measurements, findings from exploitation, etc. To

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that on add a new requirements of exploitation by extension of the functioning regimes domain in nearness of optimum regimes.

The experience accumulated up to now in the design domain of Francis turbine runner offer a great volume of information referring to options and solutions which can be adopted in diverse phases of rotor blades sizing. Getting over of these phases through classical methods, grapho-analytical, it is heavily, is necessary long time and cannot put in evidence the majority positive or negative aspect of an option taken on path. Accordingly, it is impose necessary, that all Francis turbine runner design to be realized computationally and using appropriately computer graphics.

The implementation on the computer of classical method for blade intersection with horizontal cutting planes opens out new perspectives for to solve this problem. Such as heaving the 3D coordinates of the points which represent the profiles contour from stream surfaces, defines lines segment which joint two homologous points from the contour of two consecutive profiles. Intersecting these line segments analytical defined in 3D with equidistant horizontal cutting planes will result much more points for to define the resulted curves then classical method even through that was transposed on the computer.

For case study was taken a Francis runner integral designed on the computer, heaving n_{sHP}=238 and specific speed ν=0,413.

2. Transposition in calculus algorithm of the grapho-analytical method for determination of the intersection curves of the runner blade with horizontal cutting planes

The blade images (projections) in meridian plane and in horizontal cutting plane (perpendicular on the rotating axes) are not enough for runner execution. The suction side and pressure side surfaces of the blade are curved and twisted in space and accordingly any views or sections would make after classical rules of technical design, do not obtains a contour enough clear of the blade allow for execution. Therefore it is usual to make successive intersections of the blade with parallel planes, perpendicular on the rotating axes. Cutting out in these planes the intersection contours of the blade and replace it's at the initial level, assembling of all contour planes from all horizontal cutting planes obtain a 3D interpolation of the blade surfaces. Beside technological role, the intersection with horizontal cutting planes has designation to verify the uniformity of the blade surfaces. In case that the resulted curves from the blade intersection present undulations, inflexions, etc. signify that on road was produced errors or the options in certain job step of design was not well correlation.

Starting from these considerations, the intersection with horizontal cutting planes is made after certain strategy through the obtained results to permit a reconstruction 3D of the blade at all exactly in technological processes. Thus the ranges which the horizontal cutting planes intersect the both edges (leading and trailing edge) and much sufficient streamlines, and the blade is a little curved, will be intersected by one rare fascicle of horizontal cutting planes. Another zones, heaving less stream lines or the blade been curved to outlet will be intersected with a great number of horizontal cutting planes.

For the case of analyzed runner the projection in meridian plan was divided in three zones according with fig. 1, two zones are more thicken and one is more rare. In the rare area distance between two consecutive planes is of 50 mm, and in the thicken area distance is half.

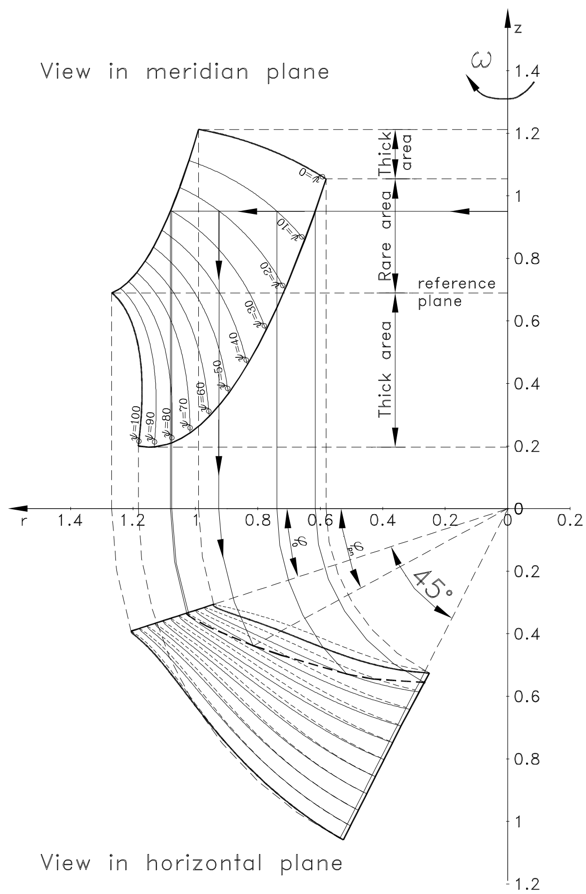

Fig. 1. The definition of intersection zones with horizontal cutting planes and the identification modality of the points resulted in projection (case suction side).

It was choused like reference plane, the plane which pass through intersection point of leading edge with shroud (to diameter D_{1e}). This plane gives the order name zero (0). Numerating order follow-up was increasing (z – grown) and was continued after down from the reference plane. The position of these planes, their numbering and zones delimitations are according to figure 2.

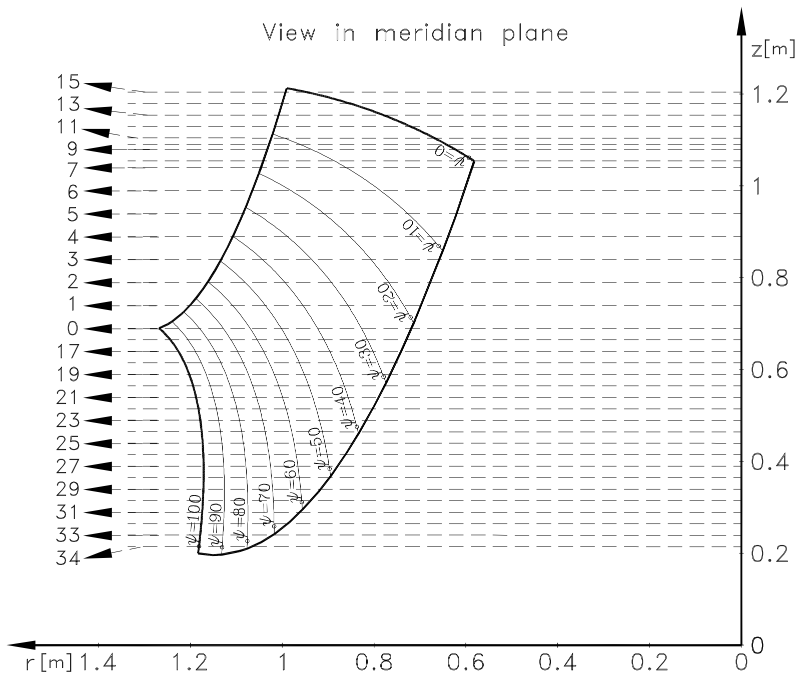

Fig. 2. Position of the horizontal cutting planes and their numbering.

Heaving defined the fascicle of horizontal cutting planes start effectively to found the intersections points. Taking for example certain horizontal cutting plane, a line in meridian plane of runner blade, this will intersect the streamlines and eventual leading edge and trailing edge. The obtained points will heave the coordinate z=const., the same for all and the corresponding radius different.

After intersection radiuses getting it come to found corresponding polar angles for to can then calculate the coordinate *x-y*. According with fig. 1 for a radius obtained it trace an arc with the same dimension which will intersect the curve in projection at a point because follow to be found polar angle. In this case will be a little difference between the polar angles of pressure side and suction side. Connecting the resulting points from the same horizontal cutting plane obtains the intersection curves (kind of collinear diagram) separate for pressure side and suction side. The resulted curves are interpolated with SPLINE function. These two figures put in evidence the shape correctness of the blade resulted and are not practical importance in a blade execution.

Grouping double curves of the same horizontal cutting plane from pressure side and suction side it obtains the image effective intersection of the plane with blade surfaces. These are presented in coordinate system *xOy* where point abscissas and ordinates calculate with relations:

$$\begin{cases} x = r \cdot \cos\varphi \\ y = r \cdot \sin\varphi \end{cases} \tag{1}$$

In view of smoothing these curves is used interpolation with SPLINE functions. In case of technological execution these curves dimension appropriately so that theirs trace on the auxiliary technological material to be at all exactly.

3. New analytical method for to found intersection curves of the runner blade with horizontal cutting planes

The new method idea is appeared from 3D representation of the rotor, respectively one blade runner. This representation suppose join with line (line segment) the homologous points from the profile contour placed on the stream surfaces. In figure 3 is presented a runner blade in 3D intersected with one horizontal cutting plane, and the two resulted parts of the body blade are translated on vertical for to put in evidence the obtained surfaces in the body blade follow-up intersection.

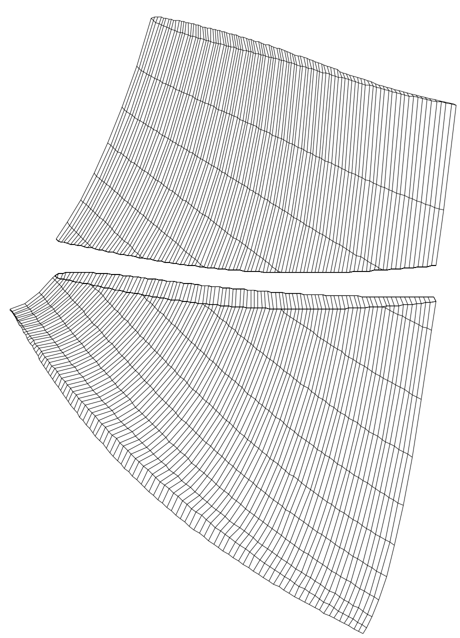

Fig. 3. The body of the blade intersected with a horizontal cutting plane and the two parts resulted and vertically translated.

It observe that using classical method of intersection obtain only the intersection points of horizontal cutting plane with pressure side, respectively suction side profiles from stream surface, id est. total 7 points for pressure side and 7 points for suction side.

By this new method it make available that every profile from stream surface is definite (it are known the coordinates *x,y,z*) in *N* points $(100 \le N \le 200)$ to pressure side and *N* points to suction side. Joining the homologous points (with the same order number) double profiles from double stream surfaces consecutively it obtain straight lines (line segments) of whom analytical equations can be written in 3D for the case of the straight line that pass through two given point of coordinates $(x_{i,j}, y_{i,j}, z_{i,j})$ respectively $(x_{i,j+1}, y_{i,j+1}, z_{i,j+1})$. The index "*i*" controls the order number of the point on the profile frontier from the stream surface, and index "*j*" controls the order number of the stream surface.

Mathematically these equations are the form [9].

$$\begin{cases} \dfrac{x - x_{i,j}}{x_{i,j+1} - x_{i,j}} = \dfrac{z - z_{i,j}}{z_{i,j+1} - z_{i,j}} \\ \dfrac{y - y_{i,j}}{y_{i,j+1} - y_{i,j}} = \dfrac{z - z_{i,j}}{z_{i,j+1} - z_{i,j}} \end{cases} \tag{2}$$

The horizontal cutting plane with order number "*k*" has in 3D the equation:

$$z = z_k \tag{3}$$

Joining these equations with the two equations from (2) will result a system of tree linear equations with tree unknowns.

$$\begin{cases} \dfrac{x - x_{i,j}}{x_{i,j+1} - x_{i,j}} = \dfrac{z - z_{i,j}}{z_{i,j+1} - z_{i,j}} \\ \dfrac{y - y_{i,j}}{y_{i,j+1} - y_{i,j}} = \dfrac{z - z_{i,j}}{z_{i,j+1} - z_{i,j}} \\ z = z_k \end{cases} \tag{4}$$

The solution of this system is immediately. Noting with "*n*" the order number of the line segments encountered by section plane in direction from leading edge to trailing edge result:

$$\begin{cases} x_{n,k} = x_{i,j} + \left(x_{i,j+1} - x_{i,j}\right)\dfrac{z_k - z_{i,j}}{z_{i,j+1} - z_{i,j}} \\ y_{n,k} = y_{i,j} + \left(y_{i,j+1} - y_{i,j}\right)\dfrac{z - z_{i,j}}{z_{i,j+1} - z_{i,j}} \\ z_{n,k} = z_k \end{cases} \tag{5}$$

Using this method the number of points obtained grows very much canning to arrive on some areas up to *N* points. Heaving more points, the intersection curves of the blades with horizontal cutting planes will be much more exactly defined.

In figure 4 and in figure 5 it is comparatively exemplified the intersection curves with the horizontal cutting planes by new method and the points obtained by the classical method, jointed with line segment. In some zones it observes evident differences between the two methods.

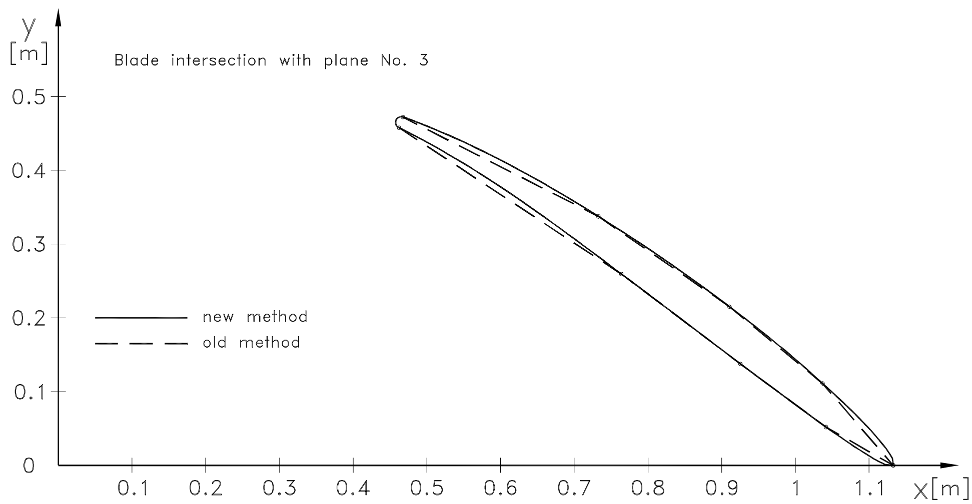

Fig. 4. The comparison of the intersection result between the old and the new method (pl. No. 3).

4. Conclusions

The described method applies with successful at Francis turbine runners and centrifugal pumps. The point and the curves of intersection are obtained with a programming algorithm and the numerical values are available for data base for manufacturing process and verification at finish.

A good definition of the blade surface get on-coming between the shapes of the blade desired and resulted.

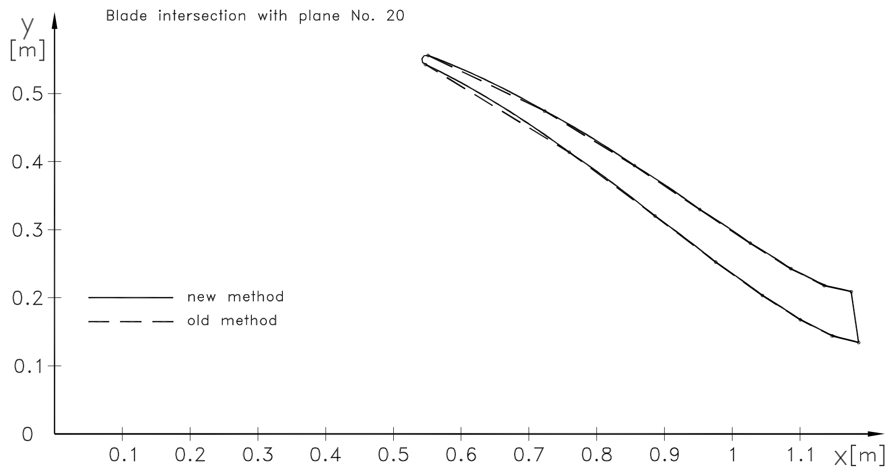

Fig. 5. The comparison of the intersection result between the old and the new method (pl. No. 19).

Acknowledgements

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