Drawing and inspection of the axial projection view of the centrifugal pump impeller

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Abstract. Artificial scaffolds play an important role in tissue engineering, which used to mimic extracellular matrix (ECM) to provide a suitable microenvironment for cell growth. Many natural and synthetic biomaterials have been used to fabricate two dimension or three dimension scaffolds. However, missing electrical conductivity of these materials is one of the disadvantages. Recently, conductive polymers (CPs) and conductive nanomaterials (CNMs) have been chosen for doping into scaffolds to improve their conductivity. This review focuses on conductive scaffolds design, fabrication and application in tissue engineering for enhancing cell attachment and proliferation, promoting differentiation and maturation with and without electrical stimulations.

1. Axial projection view
The centrifugal impeller has an axial line. The plane passing through the axis of the impeller is called axial plane or meridian plane, and one impeller has an infinite number of axial planes.

The impeller or the blades are sectioned by several axial planes, and then the axial cross-sectional views are rotated around the impeller axis and then superposed together, so an axial projection drawing of the impeller or the blade is obtained. The points of the exit edge of the blade, the entrance edge and the blade surface are located on three different axial planes. By superimposing the three axial planes together, the structure of different parts of the blade can be represented on one axial planes drawing. The distance on the drawing from one structure of the axial plane to the axis is equal to the true distance from this structure to the axis. This article describes the centrifugal pump impeller.

2. Drawing principles and methods
After the full geometry parameters (\( R_2, b_2, Z, D_0, \beta_2 \)) of the impeller are determined, the pattern of the blades should be completed according to these determined dimensions\textsuperscript{[1-2]}. For this purpose, the first work is to draw the axial projection view. The known control dimensions for guiding the axial projection are only four: impeller radius \( R_2 \), impeller inlet diameter \( D_0 \), impeller outlet width \( b_2 \), and hub radius \( e e \). The axial projection drawing of the impeller should meet these four basic dimensions, as shown in Fig.1.
Since all the geometric parameters $R_2, b_2, D_0, Z$ of the impeller have been determined, based on this, the projection view of the axial flow path of the impeller can be initially drawn. According to the known impeller geometric parameters $b_2, R_2, D_0$,

the oblique foot coordinates $a, c$ of the intersection of the axial flow channel and the axial line are given, wherein $c$ presents the distance from the intersection of the extension line of the straight portion of the flow line of the front cover and the axis line of the impeller to the origin of coordinate in the projection view of the impeller axis plane, $a$ presents the distance from the intersection of the extension line of the straight line portion of the rear cover flow line and the impeller axis line to the origin of coordinate in the projection view of the impeller axis plane. The selection principle of $a, c$ should be $a + c \leq 2b_2$. For the arc radiuses $\rho_1, \rho_2$ of the front and rear covers, they can be given by the designer within the reference range.

In addition, when drawing the axial projection view, the following two points need to be paid attention to: First of all, for the transitional arc portion of the front and rear cover flow lines, due to the arbitrariness of the given circular arc radiuses $\rho_1, \rho_2$ of the front and rear covers, based on which, the coordinates of the center of the circle are calculated, so the positions of $O_1, O_2$ are not determined. Therefore, the relative positional relationship of $O_1, O_2$ should be discussed separately when drawing the axial projection view. Secondly, for the low-specific-speed centrifugal pump, in order to improve the hydraulic efficiency of the impeller and ensure that the inlet angle of the cylindrical blade is not too large, the simple treatment is generally performed, that is, the straight portion of the outlet is an isosceles trapezoid, which is symmetrically distributed, as shown the straight lines $DG$ and $CH$ in the figure. The study considers the general case that the quadrilateral $CDGH$ is an arbitrary trapezoid. In particular, for multi-stage multi-suction pumps, for the sake of hydraulic performance and the placement of the blades, the straight portions of the DG and CH should be perpendicular to the axis.

3. Drawing steps

3.1. Determination of coordinates
First, a rectangular coordinate system (the axis line of the impeller is taken as the x-axis, and the vertical bisector of $b_2$ is taken as the y-axis, as shown in Fig. 3-1) is established. Assuming that the center of the arc of the front and rear covers are $O_1(x_{o1}, y_{o1}), O_2(x_{o2}, y_{o2})$ respectively, and the arcs of the front and rear covers and the tangent points of the line are $E(x_E, y_E), F(x_F, y_F)$, respectively.
Considering the general situation, the hub radius is $ee$ the axial projection view shows that the coordinates of each vertex are:

- Coordinate of point $C: x_C = b_2 / 2, y_C = R_2$;
- Coordinate of point $D: x_D = -b_2 / 2, y_D = R_2$;
- Coordinate of point $G: x_G = -c, y_G = 0$;
- Coordinate of point $H: x_H = a, y_G = 0$

The DG line equation is: $y = kx + ck$ (where $k = \frac{R_2}{c - b_2 / 2}$) \hspace{1cm} (1)

The CH line equation is: $y = lx - al$ (where $l = \frac{R_2}{b_2 / 2 - a}$) \hspace{1cm} (2)

### 3.2. Determination of the coordinates of $O_1$

The front cover transition arc is tangent to the horizontal line $y = D_0 / 2$, so the ordinate of the circle center $O_1$ should be:

$$y_{o1} = \rho_1 + D_0 / 2$$ \hspace{1cm} (3)

The front cover transition arc is tangent to the straight line DG at point E, and the horizontal line drawn through $O_1$ intersects with DG at point J ($x_j, y_j$), so $y_j = y_{o1}$. Because point J is on the straight line DG, it can be obtained by equation (1):

$$y_j = kx_j + ck$$ \hspace{1cm} (4)

Therefore, the abscissa of the point J can be calculated:

$$x_j = \frac{y_{o1} - ck}{k}$$ \hspace{1cm} (5)

After the coordinates of point J are known, the abscissa of the center $O_1$ of the circle can be obtained and shown as:

$$x_{o1} = x_j - [O_1J] = -\left(\frac{\rho_1}{\sin(\arctg(k))}\right) + \left(\frac{ck - y_{o1}}{k}\right) = -\left(\frac{\rho_1}{\sin(\arctg(k))}\right) + \left(\frac{ck - \rho_1 - D_0 / 2}{k}\right)$$ \hspace{1cm} (6)

The straight line $O_1E$ is perpendicular to DG:

$$\frac{y_{o1} - y_E}{x_{o1} - x_E} \times k = -1$$ \hspace{1cm} (7)

Combined equation (3-1) and (3-7), the coordinate of the tangent point E are:

$$x_E = \frac{y_{o1} - ck}{k} + \frac{x_{o1}}{k} \hspace{1cm} y_E = kx_E + ck$$ \hspace{1cm} (8)

### 3.3. Determination of the coordinates of $O_2$

The center of the circle can be obtained in the same way, but it should be noted that for a multi-stage multi-suction centrifugal pump, there is a case where the rear cover flow line is perpendicular to the axis line, which should be discussed separately here.
In general, when the straight line portion of the rear cover streamline (ie, the straight line segment CH) is not perpendicular to the axis line: The transition arc is tangent to the straight line CH at the point F, and the horizontal line drawn through $O_2$ intersects with CH at point M $(x_M, y_M)$. Since the point F is the tangent point and the slope of the line CH is less than zero, the point F is higher than the point M. First the ordinate of the point $O_2$ is calculated:

$$y_{o2} = \rho_2 + ee \quad \text{------------------------ (9)}$$

Then the coordinates of point M are calculated:

$$x_M = \frac{y_{o2} + al}{l}, y_M = y_{o2} \quad \text{------------------------ (10)}$$

The abscissa of the center $O_2$ of the circle can be calculated by point M:

$$x_{o2} = x_M - |O_2M| = \frac{y_{o2} + al}{l} - \frac{\rho_2}{\cos(\arctg(l) + \pi/2)}$$

$$= \frac{\rho_2 + ee + al}{l} - \frac{\rho_2}{\cos(\arctg(l) + \pi/2)} \quad \text{------------------------ (11)}$$

Straight line $O_2F$ is perpendicular to CH:

$$\frac{y_{o2} - y_F}{x_{o2} - x_F} \times l = -1 \quad \text{------------------------ (12)}$$

Combining the equations (2) and (12), the coordinates of the tangent point F is calculated:

$$x_F = \frac{y_{o2} + al + x_{o2}}{l + \frac{l}{1}}, y_F = lx_F - al \quad \text{------------------------ (13)}$$

In the case where the straight line portion of the rear cover streamline (ie, the straight line segment CH) is perpendicular to the axis line: The transition arc is tangent to the straight line CH at the point F, and the horizontal line drawn through $O_1$ intersects with CH at point M $(x_M, y_M)$. Since the point F is a tangent point and the slope of the line CH does not exist, the point F coincides with the point M. First the ordinate of the point $O_2$ is calculated:

$$y_{o2} = \rho_2 + ee \quad \text{------------------------ (14)}$$

Since $O_2$ is on the same level as point F, so:

$$x_{o2} = a - \rho_2 \quad \text{------------------------ (15)}$$

$$x_F = a, \ y_F = y_{o2} \quad \text{------------------------ (16)}$$

In this way, the coordinates of all the vertices of the axial plane projection of the impeller and the coordinates $O_1, O_2$ of the arc center of the front and rear covers are obtained, and the position coordinates of the two tangent points E and F are obtained. From these coordinates, in the already established coordinate system, the axial projection view can be drawn. It should be emphasized here that due to the arbitrariness of the arcs $\rho_1, \rho_2$ of the front and rear covers, different axial projections view are formed.

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