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Generation of Curved Blade Profile of Centrifugal Fan Using MATLAB

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Abstract
This paper presents concise and accurate programing methodology to develop the curve blade profile of radial type centrifugal fan or pumps using MATLAB. This procedure can produce any number of intermediate points between boundary points which would make the profile sufficiently smooth and precise while the manual or CAD method would have been tedious and time consuming to generate suffucient number of points. There are limited numbers of papers which provide simple and quick method to generate accurate blade profile as per design from the given value of inlet and outlet diameters with corresponding profile angles. The accuracy of the curve generated through those points depends on the number of intermediate points; greater is the number, the curve becomes more accurate. Manual generation through drawing or cad to find large number of points is quite tedious and time consuming and hence a MATLAB program is developed in which a powerful code can develop any number of intermediate points.

Keywords
Centrifugal Fan – Blower – Vane Profile – Brick Kiln

1. Introduction

Centrifugal pumps and fans are the most universally used Turbo machineries for increasing fluid energy from the rotational mechanical energy. Impeller of the device is the principal parts which consist of blade in order to impel fluid to move from lower energy level to higher energy region. During the design of the impeller, almost all mathematical models provide just the inner and outer radius with blade angles which are just the boundary values for the blade profile using which intermediate points have to be generated using various methods.

2. Selection of Impeller

Radial tip Impeller of centrifugal blower designed for the brick kiln plant to flow air to the chimney is taken here as a case. The selection of radial tip blade impeller is due to the consideration of dust laden condition of the gases produced in brick kiln. Radial blades are ideal for dust laden air or gas because they are less prone to blockage, dust erosion and failure and have self-cleaning properties[1].

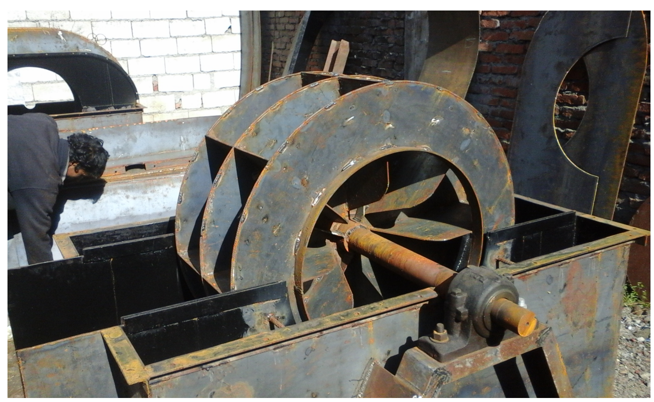

Figure 1: Centrifugal Blower used in Brick kiln

2.1 Design Parameters

The impeller was designed for brick manufacturing requirement of Nepal for which design parameters are flow rate of 5kg/s (double inlet condition) with pressure difference requirement of 410 Pascal as suggested by the brick kiln manual. The rotational speed for the blower is selected with the tradeoff between the size of the impeller and the aerodynamic efficiency as decreasing speed increases the efficiency reducing dynamic problems such as noise, eccentricity while increases the size of the impeller setting higher manufacturing and material cost. The figure below explains the finding:

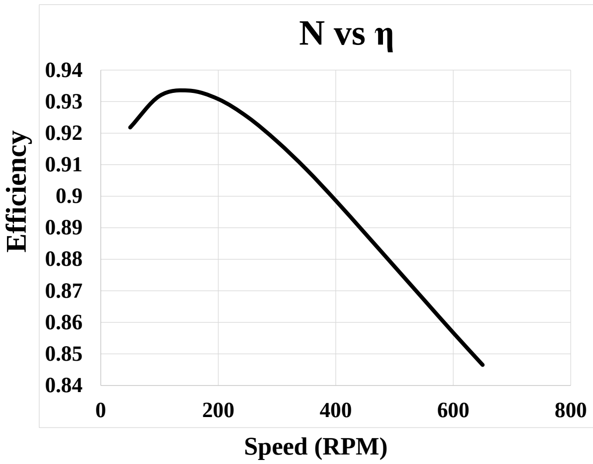

Figure 2: Effect of RPM with Efficiency

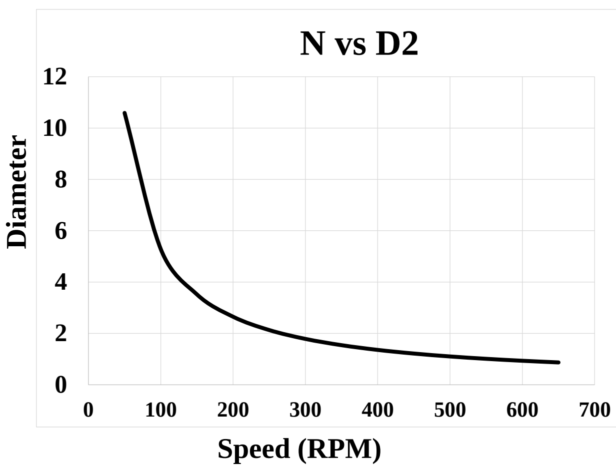

Figure 3: Effect of RPM with External Diameter

2.2 Design of impeller

The design of the centrifugal radial tip impeller is formed with the fundamental theory of fluid mechanics. [2, 3] The major requirement for the blade profile generation is summarized in Table 1.

The values for β_1 and β_2 are selected as 42.7 degree and 90 degree as from the design. For smooth flow, the vane must be designed such that this angle increases smoothly from 42.7 degree to 90 degree. There are several methods to construct the vane shapes. The one used in practice consists of tangent circular arc. The

Table 1: Major requirement for the blade profile generation

SN	description	Value
1	impeller inlet diameter, mm	512
2	impeller outlet diameter, mm	1080
3	inlet angle of blade	42.7
4	blade outlet angle	90
5	mass flow rate, kg/sec	2.5
6	pressure difference, Pascal	410
7	Rotational speed, rpm	510

radius of the Circular arc contained between the rings D_1 and D_2 is given by[4],

$$R_b = \frac{R_1^2 - R_1^2}{2[R_1.cos\beta_1 - R_2.cos\beta_2]} \tag{1}$$

Where, R_1 and R_2 are the radii of corresponding Inner and Outer radii of the arc section of impeller.

These radii are the intermediate radius found by dividing the inner and outer diameter of the impeller into a number of concentric rings not necessarily equally spaced. Now, the values of radius of each intermediate concentric circle can be calculated as $\frac{R_1 - R_1}{n}$ where, n being the number of intermediate concentric rings required.

2.3 Use of MATLAB

MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numerical computation. Using MATLAB, you can solve technical computing problems faster than with traditional programming languages, such as C, C++, and FORTRAN.

Use of MATLAB to generate profile of radial tip centrifugal fan involves following steps shown by algorithm as follow:

The following algorithm has been presented in simplified form as much as possible in order to make it explicable for all. The detail of the logic, if presented in the algorithm, renders it implicit and hence only a simple form has been created.

- Start
- Read input Variables Rin, Rout, β1and β2 and n
- Find all intermediate values of radius of arc Si using interpolation
- Take P(-Rin, 0) as intial inlet point of the blade profile
- Find centre of arc Rb from initial point with β1 , as C1 (-Rin+ S1*cos β1 , S1* sin β1)
- Set i=1 to i=n
  - Find intersection of the circle C and next intermediate circle
  - Replace point P(Px , Py) with the intersection point whose ordinate value is greater
  - Find slope angle Φ of center of circle C and new P using two point slope formula
  - If i<n,
  - Find new center of circle Ci+1 (Px + Si+1*cos Φ, Py + Si+1* sinΦ)
  - Repeat
- Print points P
- End

The algorithm is a logic which can be applied to any programming language like C or C++. Because of large pool of user defined function which develops user friendly programming environment to the programmer, MATLAB is preferable.

The local notations use in the above syntax can be set by the designer as per their preference. The syntax is saved in .m format which can be directly executed to MATLAB command window. While operation, the program ask for the value of inner and outer radius with respective profile angles along with the number of points needed. The required points are displayed in a row after the execution of the program which can be saved in .txt format by copying it to the notepad. According to our requirement of the radial tip centrifugal fan to be used in brick kiln of NEPAL, the required input variables are summerized as follow;

- R_{in} =258
- R_{out} = 540
- β_1 =42.27
- β_1 =90
- n=30

The value of n is taken as 30 which is sufficient in to generate spline curve with reference to our design blade profile.

3. Result

As the profile of the radial tip blade is the two-dimensional distributions, the output consists of only two dimension points are shown in the result. The third dimensional value must be made as zero in order to import the point in solidworks to generate spline curve.

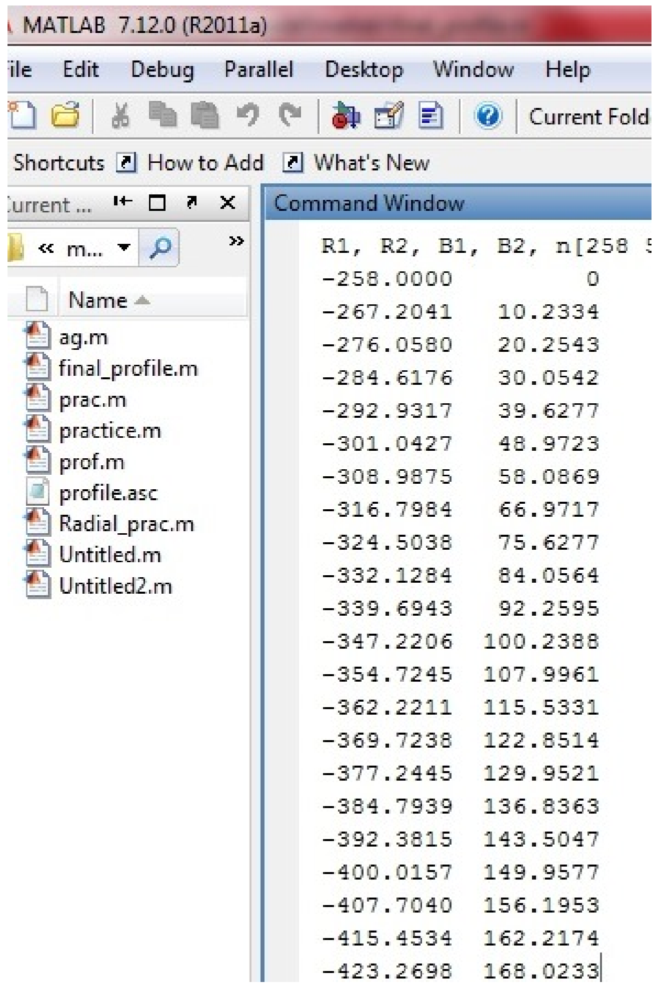

Figure 4: Points generated in MATLAB

The output of the MATLAB program is as follows: The above points are first saved in ".txt" format through notepad which can be directly imported to SOLIDWORKS. The resultant curve generated with the SOLIDWORKS is the spline curve joining all the generated points. Hence the profile curve is shown in figure below.

The generate curve of the fan blade profile, now can be

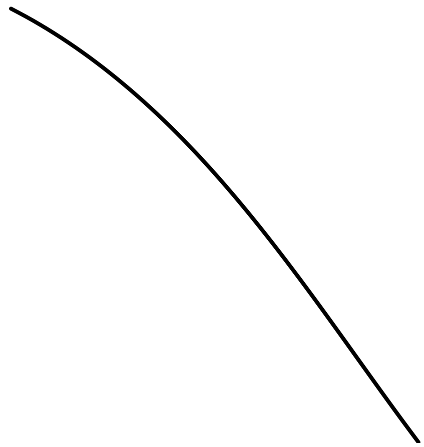

Figure 5: Profile curve imported

further modeled to create 3- D model with the design specification in SOLIDWORKS.

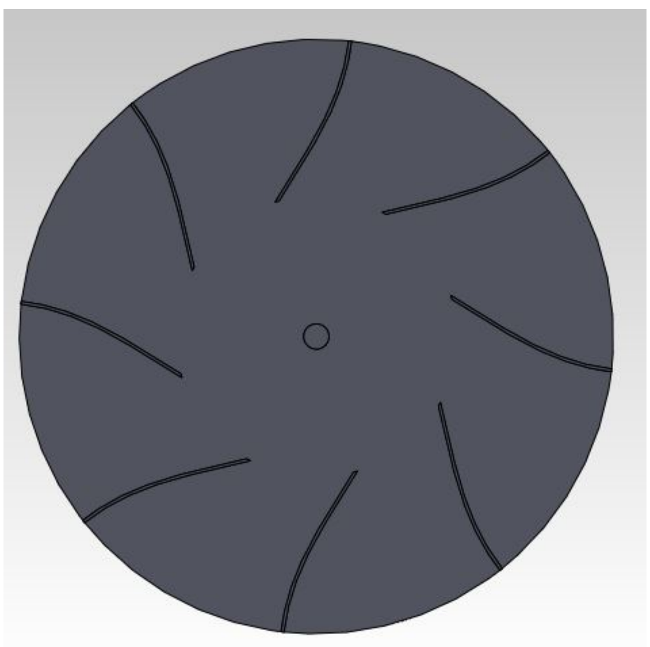

Figure 6: Solid Model of the Impeller

4. Conclusion

This paper thus presents accurate and precise, working radial type vane profile design procedure by using MATLAB programing. This procedure is quite fast can generate any number of intermediate points until the designer feel sufficiency with high level of accuracy. Hence impeller of any dimension with known values of inlet and outlet diameters with corresponding profile angle, smooth profile curve can be generated and initiate the 3D modeling of the impeller for further analysis and simulation supporting producer in making the manufacturing decision more quickly.

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