# Applying Computer Aided Designing for Steam Turbine Blade

Deepak Singh
Asst. Professor, Department of Mechanical Engineering
Kautilya Institute of Technology and Engineering, Sitapura,
Jaipur, India
singhdeep_77@rediffmail.com

*Abstract*- **Modern industries are using CAD models for the accurately representation of geometry for designing and manufacturing of turbines. The CAD model provide a more realistic analysis of performance of the product, this task included dimensional measurement and geometric modeling. This paper presented the procedure for how to achieve CAD model of turbine blade. The method discussed here is the latest profile developed for blades involves regularization and curve fittings using Bazier and B-spline curve generation . Weighting coefficients and nurbs are used for curvature surface of the model.**

**Keywords- Cascade; Blade;**

## I INTRODUCTION

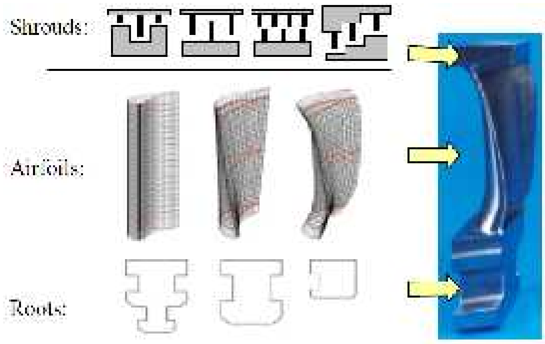
Turbine blade playas main role in absorbing the energy from the dynamics of fluid and converted into mechanical energy. These Blades are fabricated in the desired size and shape and assembled in a straight line or annular according to the designing of cascade. The designating of cascade is based on the database which contains a set of turbine cascades with their geometry and operating conditions. In general, there are two methods for blade profile design i.e. inverse method, and direct method. The inverse design is faster because it is based on the two-dimensional flow analysis to form the airfoil according to the airfoil pressure profile. However, the location of the profile control points is difficult to control and numbers of arcs are generally large. This makes it difficult to use the same curve definition routine for design and manufacturing. On the other hand, direct design may require more time in the aerodynamic design process, but can generate more accurate designs in the manufacturing process. In turbulent flow analysis is needed to evaluate the blade performance.

## II. BLADE PROFILE

A turbo machine blade is usually a cantilever beam or plate is tapered and twisted with an airfoil cross-section. Typically a turbo machine has several stages, each stage with a stator and rotor. The function of stator is to guide the flow medium at an appropriate entry angle into rotor blades. The rotor blades are mounted on a disc at a stagger angle to the machine axis and they convert the thermal energy into mechanical energy in turbine. In turbine steam enters at high pressure and temperature in the first stage and expands while passing through the several stages before it is let out from the last Stage with low temperature and pressure after extracting as much as thermal energy as possible. Shape of the turbine is frustum conical type, small blades are assembled in first stage then size of blade increases progressively. Hence, the short blades in high pressure have high frequency to progressively lower up to the last stage long blades. The initial stages of the blades are designed with a variable degree of reaction. The design of these integrally shrouded blades results in an elastically pre-stressed blade ring after assembly that is characterized by an excellent damping behavior during operation. This robust and proven blade construction through long experience converts highly efficient three-dimensional airfoil designs. Within the blade path section interlocking labyrinth seals are applied. Since the overall efficiency of steam turbine power plants is very strongly related to the turbine blading performance, it is necessary to design each turbine blade path individually. It is very cumbersome method of design and can be easily achieved through application of Computer Aided Design (CAD).

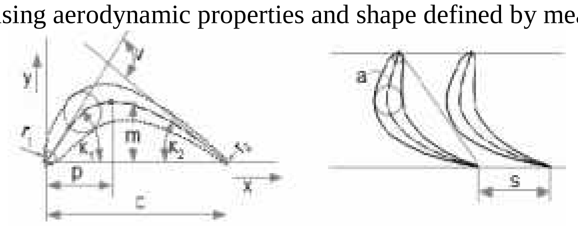
CAD is very popular among the manufacturers due to many advantages like CAD has ability to create fast designing to meet today's tight design lead times. We can do fast modifications in developed parts in order to match the desired efficiency and performance levels in each particular application.

Developing the blades with CAD facilitate a highly standardized and flexible blading technology. This is essentially based upon the latest generation of highly efficient fully three-dimensional blading with compound lean and variable stage reaction. However, since not only the technology but also the quality and speed of the design process decide whether the overall performance and lead time requirements are met, the entire blade path design process has been automated within a very powerful design system. Design automation enables more design cycles in a given time and hence leads to a much more efficient design process reaching a better optimum in a shorter period of time. Thus, from this automation significant cost and time savings due to accelerated and robust processes can be achieved, while at the same time a contract specific bladepath. design with optimum efficiencies is delivered to the customer. Different to the other elements of the steam turbine, the primary goal of standardization with regard to HP/IP blading has been to standardize the "way to the product" instead of the product itself. By using CAD we can create modular concept of bladepath construction from standard and proven elements (e.g. airfoils, roots, grooves, shrouds, extractions, locking devices). The composition of a single blade from root, shroud and airfoil is demonstrated.



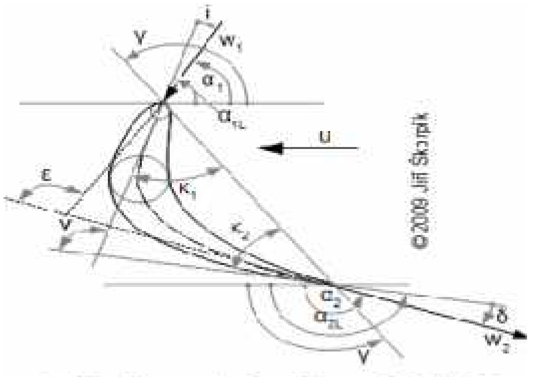

By assembly of each element with different types of another element exist for the various applications, so we may analysis of each type to measure advantages and disadvantages with respect to performance, mechanics and costs. Within the modular concept all these different types may be combined freely to give an optimum blade for the specific design boundary conditions such as aerodynamics, forces, materials and temperatures. Hence, cylindrical, twisted or bowed airfoils can be assembled with any of the roots or shrouds.

A. Shape of blade profile: The shape of a blade profile is function of a velocity triangle and an aerodynamic calculation. The shape of the blade profile must be defined through a suitable method with considering manufacturing point of view. It is very conveniently obtained through CAD systems by using vector graphic, because machine-tools are able to work with these inputs directly. Before determining CAD procedure for blade let we understand the geometry of the blade profile. The blade position inside the blade row is described by a few geometrically and aerodynamically angles, The geometrically parameters of the blade row has variable influence on their function. When we change the angle of blade profile inside blade row in the steam turbine it will affect the change of momentum of a jet of steam flowing over a curved vane. The steam jet, in moving over the curved surface of the blade, exerts a pressure on the blade owing to its centrifugal force. This centrifugal pressure is exerted normal to the blade surface and acts along the whole length of the blade. The resultant of these centrifugal pressures, plus the effect of change of velocity, is the motive force on the blade. Blade profile is made of airfoil by using aerodynamic properties and shape defined by mean camber line.



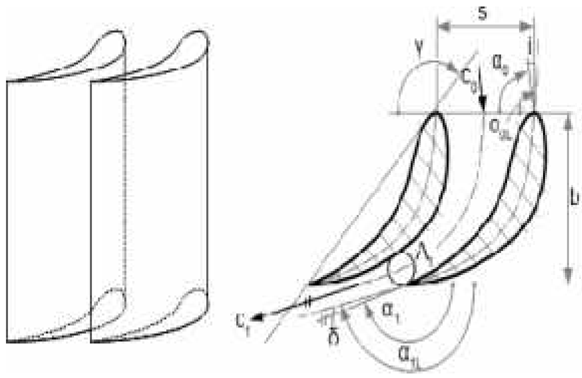

*Description of the profile curves are shown in the figure.*

As indicated in the fig. m is the maximum camber; p is the position of maximum camber; κ1, κ2 are the angles of the mean camber line (on the leading edge and the trailing edge the camber); c is the length of the chord line; s is the pitch. The blade profiles are generated by performing experiments on various blade profiles by changing their angles. The shape of the mean camber line usually has a shape of the circle, parabolic ,others geometric fundamentals curves or combination of two curves connected in the maximum camber point through together tangent. The terms and the signs of the blade profile geometry can be various. It depends on convention applied in the country. Therefore it is necessary wrote this convention with the descriptions of the shape of the blade profile. Here are used the terms and the sings by that are usually Fundamental geometric and aerodynamic angles of blade profiles are mentioned these are as shown in following figure




$i=\alpha_{1L}-\alpha_1,\quad \delta=\alpha_{2L}-\alpha_2,\quad \varepsilon=v+i-\delta$

Y is angle of blade profile inside a blade row; $\alpha_{1L}$ is the blade inlet angle; α2L is the blade exit angle; i is the angle of attack (incidence); δ is the angle of deviation; ε is the angle of camber of flow; $\mathbf{w_1}$ the velocity of attack; $\mathbf{w_2}$ Others system of the angles be can use, for example the systems, which are shown in leaving velocity parameters (total pressure loss coefficient, exit flow angle, deviation angle).The pitch of a blade cascade is design from an appropriate density of the blade rows: Density of the blade row and comparative pitch is shown below




Creating **Geometry and aerodynamic characteristics of blade rows** The design approach is based on the definition of the cascade by the parameters with their geometry and operating conditions. That forms the artificial intelligence technique. For the geometrical representation of a Turbomachinery cascade a Bezier curve based approach has been used. The geometry of the Turbomachinery cascade is then completed by adding the pitch/chord ratio. The independent variables that define the cascade geometry are sixteen in total. These quantities will be the output values for the CAD. For each turbine cascade the database contains the above set of quantities for the geometrical representation, the operating conditions (inlet flow angle, exit Mach number) and the performance B- spline representation for heterogeneous representation for homogeneous object :ensor product solid representation has been widely used in CAD geometry design community.

## III BLADE GEOMETRY

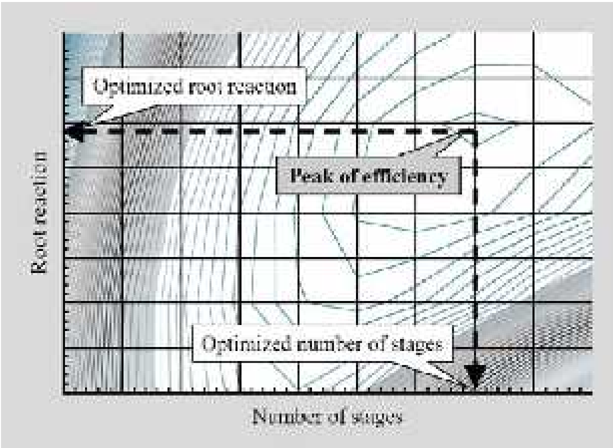
The geometry of a turbine profile with specified performance is generated with an innovative inverse design technique or direct design, based on total sixteen independent variables and are in a Cascade . These Variables are many dependent and independent variables. Important variables are Reynolds no., Mach number, Pitch chord ratio, Aspect Ratio, Blade Geometry and profile, Boundary layer and degree of turbulence, incidence. All these parameters have a broad range of variations , so a finite test program is obvious impossible. In the development or design of blade row some parameters are fixed by the given conditions and others parameters have marginal effect. Therefore, the variables involved can be reduced to a more practical and manageable member. In this paper our main focus will be concentrated on the blade geometry and profile. In the development of the blades mainly study the effect of blade profiles is important for the performance. In the Profile effects of leading and trailing edge shapes are important in designing of blades because of the high stresses in the blade are influenced by these factors.

The CAD is using the data stored in the database and then developed cascade geometry based on sixteen output values with a given in performance (total pressure loss coefficient, exit flow angle) during specified operating conditions.

In order to guarantee a homogeneous set of performance data in the database, the aerodynamic performance stored in the database for all the cascade configurations have been computed using the same Navier-Stokes method (with the same mesh density) that was also implemented into the optimisation procedure.

The additional set of cascades from the open literature have been geometrically parameterised using the same Bezier approach previously described. In order to obtain the set of geometrical parameters (fifteen) for the aerodynamic profile from the Cartesian co-ordinates available, an optimization technique has been set up as sketched The set of variables for the Bezier representation of a given reference profile are obtained by minimizing the distance between the co-ordinates of the actual profile and the reference co-ordinates. In the reference co-ordinates and the Bezier representation of the staggered turbine

To improve internal efficiency of steam turbines, reduced root diameter and increased number of stages is one of the important strategies for design. In order to accomplish this, optimization of parameters such as stage number, blade root diameter and the degree of reaction are required. After careful selection of optimized points, the combination of stage number and the degree of reaction that gives highest turbine efficiency is used for design.

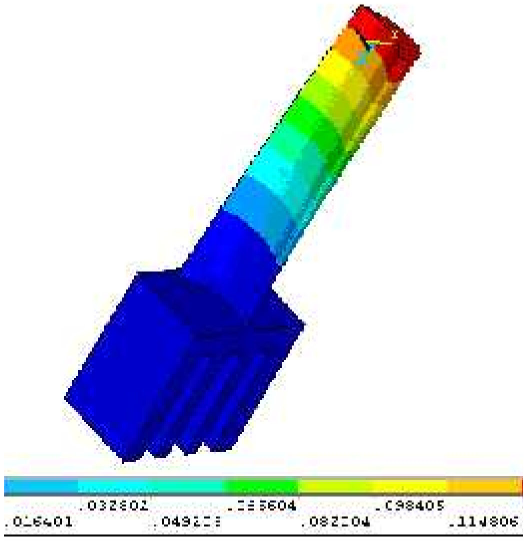



Contour lines represent the distribution of turbine efficiency and it is clear that peak of efficiency exists at certain combinations of stage number and degree of reaction.

To maximize efficiency, it is important that as many stages as possible are used in retrofit turbine within the limited bearing span. Deciding stages in the turbine efficiently is very easy by using CAD technology as an example before retrofit, the HP section was comprised of 6 stages. As a result of applying the improved design with the help of CAD, number of stages in HP section is increased to 11 stages after retrofit.
The IP section was comprised of 4 stages before retrofit. Due to the midpoint extraction, there was some restriction to increase the number of stages. However, by applying the latest CAD technology and improved design, it is possible to add two additional stages. In this case, one stage upstream and one stage downstream are added to maintain extraction pressure. Hence, after retrofit, number of stages in IP section is increased to 6 stages.
As a result of the optimized steam path design, following features are achieved for performance improvement:
1) Increased number of stages with increased stage reaction, reduced nozzle exit velocity and blade turning angle,
2) Higher aspect ratio blade and reduced root diameter resulting in reduced end-wall and leakage loss.
3) Axial entry dovetail design reduces the blade axial length to allow increased number of stages.

## VI DESIGN OPTIMIZATION

3d blade design using CAD has been introduced to improve efficiency and minimize incident losses. We can develop steam turbine blade of optimised size base on the analysis using CAD softwares. An optimization of reaction blade design in the turbine stages is to make blade lengths comparatively smaller and to optimize degree of reaction, number of stages and blade root diameters. At the last stages upstream of fixed design LP stages. When the blade become longer and longer, the difference in ratio between flow velocity and blade rotating speed at hub and tip diameter respectively, becomes larger and larger. Thus the velocity vectors over the blade length change dramatically and it is no longer possible to find an optimized blade with a straight profile. With twisted 3D profile over the length of the blade, incident angles can be kept constant, thus avoiding the corresponding incident losses. Additional effects are achieved in the shroud sealing, where the twisted blade profile gives a stronger support for the integral shroud plate, and an additional number of seal strips can be used to decrease the leakage losses still further. In addition, robust design on the bucket leading edge configuration based on statistical theory of design of experiment was carried out. As a result, it was observed that by optimizing the pitch-chord ratio, number of moving blade can be reduced by three-dimensional stage flow analysis. It can be observed that total pressure loss of cascade for optimized reaction blade decreases along almost the entire flow path. Also, it can be seen that the optimized profile reduces total pressure loss downstream from the trailing edge. The curve and surface of turbine blade in general have a Bezier or a B-spline curve representation. B-spline curve is applied for the blade simply to shorten the computational time. There is no technical difficulty to extend the methodology to nurbs volume.




**VARIATION OF GEOMETRY SHAPE AFTER APPLYING LOADS.**

**RESULTS OF FEM USING ANSYS**

| **Structural analysis** | |
|---|---|
| **Material** | **Stainless Steel** |
| Stress | 339.07 |
| displacement | 0.147608 |
| **Thermal analysis** | |
| Temperature | 533 |
| Thermal gradient | 715.055 |
| Thermal flux | 11.727 |

Finite element results for free standing blades give a complete picture of structural characteristics, which can utilized for the improvement in the design and optimization of the operating conditions. Initially a Study on different materials performed to choose best for the optimized turbine blade.

The results of Testing of Different materials for turbine blade suggested best material as using cast iron with partially stabilized zirconium coating is more beneficial than previous materials, due to low stress displacement, good thermal strength, low cost and easy to manufacture.

## V CONCLUSION

The blade with complicated airfoil construction is benefited designed by CAD technology which is allow the airfoil shape to be enhanced to the varying steam conditions between the base and tip of the blade. This design is a considerable advantage over the previous generation of the typical parallel-sided airfoil. In shorter blades, relatively large end-wall losses occur at the hub and shroud (secondary losses). Bowing the blades at the hub and shroud boundary improves the flow conditions at the end walls and minimizes losses. Longer blades are of twisted design depending on the hub-to-tip ratio, whereby each profile section is adapted to suit the local inlet and exit angle conditions. The blade profiles themselves have also been improved using numerical optimization methods to provide better flow and strength properties.

## REFERENCES

[1] S. Senoo et al., " Development of titanium 3600rpm-50inch and 3000rpm-60inch Last stage blede turbines,' Proceedings of IGTC 2011, IGTC2011-0249, pp. 1-8(2011).

[2] S.Senoo, " Development of design method for supersonic Turbine Aerofoils near the Tip of Long Blades in Steam Turbine Prat 1: Overall Configuration," Proceeding of ASME Turbo Expo 2012, GT2012-68218,pp 1-12(2012).

[3] Deckers, M., Doerwald, D. (1997). Steam Turbine Flow Path Optimizations for Improved Efficiency, Proceedings of owerGen Asia, Singapore.

[4] Simon V., Stephan, I., Bell, R.M., Capelle, U., Deckers, M Schnaus, J., Simkine, M. (1997). Axial Steam Turbines with Variable Reaction Blading, Advances in Turbine Material, Design and Manufacturing, Proceedings of the 4th International Charles Parsons Conference, pp. 46-60, London.

[5] Deckers, M., Hadden S.G.C., Pfitzinger, E.W., Simon, V. (2000). A Novel Bladepath Design System for Advanced Steam Turbines, Proceedings of the 4th European Conference on Turbomachinery – Fluid Dynamics and Thermodynamics 2000, Firenze, Italy.

[6] Jarrett, J.P., Dawes, W.N., Clarkson, P.J. (2002). Accelerating Turbomachinery Design, Proceedings of ASME Turbo Expo2002, Amsterdam, The Netherlands.

[7] Pfitzinger, E.W., Deckers, M., de Lazzer, A. (2003). Standardised Flexibility in Advanced Blading Technologies for Highly Efficient Steam Turbines, Proceedings of "XXXV. sraftwerkstechnisches Kolloquium 2003", Dresden, Germany.

[8] Schwarz, M.-A., Heine, W.-H., Wechsung, M., Tamme, R.(2003). Neue Dampfturbinengeneration für zukünftige GuD-Anwendungen, Proceedings of "XXXV. Kraftwerkstechnisches Kolloquium 2003", Dresden, Germany.

[9] Engelbert, C., Fadok, J.J, Fuller, R.A, Lüneburg, B. (2004). Introducing the 1S.W501GSingle-Shaft Combined- Cycle Reference Power Plant, Proceedings of ASME Power Baltimore, Maryland.

[10] Kern, T.-U., Wieghardt, K. (2000). The Application of HighTemperature 10Cr Materials in Steam Power Plants. VGB-ESKOM International Materials Conference, Pretoria, South Africa. Design And Materials For Modern Steam Turbines MW Helmut Pollak Ernst-Wilhelm fitzinger Norbert Thamm Mark-André Schwar (2010).

[11] Measurement-based updating of turbine blade CAD models: a case study MIHAILO RISTIC, DJORDJE BRUJIC and IAIN AINSWORTHINT. J. COMPUTER INTEGRATED MANUFACTURING, JUNE 2004, VOL. 17, NO. 4, 352–363 CAD-Based Parametric Cross-Section Designer for Gas Turbine Engine MDO Applications Christopher Dye1, Joseph B. Staubach2, Diane Emmerson3 and C. Greg Jensen4 Fluid Mechanics, Thermodynamics of Turbomachinery Fifth Edition, in SI/Metric units.

[12] S. L. Dixon, B.Eng., Ph.D. Senior Fellow at the University of Liverpool.

[13] BMWRolls-Royce GmbH, Dahlewitz, Germany A Parametric Blade Design System (Part I + II) Jürgen M. Anders and Jörg Haarmeyer Deros,