

LATEST TRENDS IN LARGE RATING STEAM TURBINE BLADING

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SYNOPSIS

Limited primary energy resources and awareness of environmental pollution has led to ever increasing endeavour to develop new steam turbine power plants with the highest possible efficiencies. Considering their output, even small step increase in efficiency can result in major savings for the customers. As overall cycle efficiency is strongly dependent on steam turbine performance, continuous improvements are sought to increase the turbine efficiency. These efforts are directed primarily towards improvement in blading as the key component of the turbine. This paper presents the BHEL readiness to meet the requirement of higher efficiency by adapting newer blading, which can substantially improve stage efficiency and hence overall performance of the turbine. Also it contains the new developments in the area of shrouds and sealings of flowpath of steam which impact overall efficiency of steam turbine. It also includes a brief about the state-of-the-art manufacturing facilities established at BHEL, Hardwar for manufacturing advance class blading.

1. INTRODUCTION

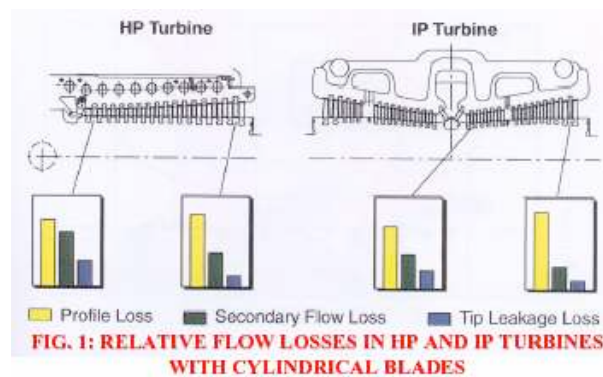
In the era of fierce competition due to liberalisation of the energy market, one of primary task associated with the development of modern power plant is to reduce the cost of power generation so as to maximise the return quickly. Higher level of efficiency is therefore demanded from present day thermal generating units. For given steam conditions and site location, the overall efficiency can be improved only by improving the efficiency of steam flowpath by minimizing the energy losses.

Turbine blading being the most crucial component of the flow path has been the focal point for improving the efficiency. A great deal of research and development efforts have been put into the redesign of the turbine blading aimed at reducing the aerodynamic losses. The flow through the steam turbines is of extreme complexity and three-dimensional owing to effects of viscosity, compressibility and unsteadiness caused by relative motion of the adjacent blade rows. 3-dimensional computational tools like CFD techniques developed in past fifteen years have helped a lot in dealing with these complexities. Using these techniques, high performance advance blading have been developed for HP/ IP and LP sections of steam turbine.

2. HIGH PRESSURE AND INTERMEDIATE PRESSURE BLADING

In reaction steam turbines, the high pressure and intermediate pressure blades so far have been of cylindrical design, i.e. with a constant profile over the entire length of the blade. The profiles used are optimised with respect to profile losses and section modulus. Fig. 1 shows the relative flow losses at various points of HP and IP turbines.

The blade profile losses account for major part of these losses. The front stages of the turbine exhibit relatively high secondary losses (which is the loss due to the development and turning of boundary layer along the hub and the casing).



A modern blade design for this portion of the turbine must therefore reduce secondary losses. Leakage losses are also relatively high at the admission sections of the HP and IP turbines. Designs minimizing leakages are therefore required to bring efficiency gains at these locations.

Development of new improved TX profile for cylindrical blade stages now affords a higher overall stage efficiency compared to so far used T4 profile. While the earlier T4 profile with its very flat optimum efficiency curve was suitable for a very wide range of applications, the new TX profile yields advantages for part-load operation over a pre-defined load range. This is in-line with current operating practice for large steam turbines. TX blades show an efficiency improvement of 0.2% over T4 blades.

The initial stages of HP and IP turbine exhibit relatively high secondary flow losses due to low volume flow rates and low aspect ratio (blade height to chord).

The inlet boundary layer separation takes place at the end wall region due to pressure difference between the pressure and suction surfaces of the steam flow channel. This leads to formation of vortices.

The losses on account of these vortices formation are classified as secondary flow losses.

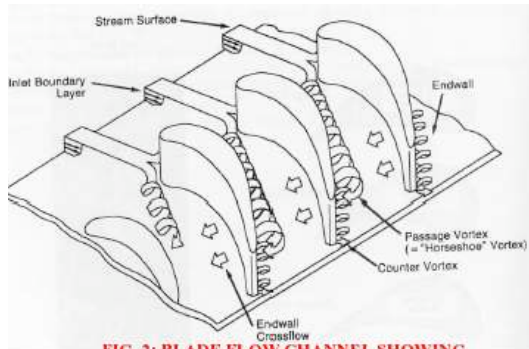


FIG. 2: BLADE FLOW CHANNEL SHOWING SECONDARY FLOW LOSSES



FIG. 3: 3DS BLADES

For usages in these stages, three dimensional (3DS) blades have been developed to enhance efficiency by reducing secondary losses. The design is characterised by the inclination of the profile part of the blade in root and shroud regions. This angling of the blade imparts an additional force on the steam opposite to the force due to pressure difference between the pressure and suction side of the flow channel. This results in lower aerodynamic force due to reduced pressure difference between the suction and pressure sides, hence reducing the driving force for cascade vortices, the main source of secondary losses.

A 3DS blade is shown in the figure 3. 3DS blades show an efficiency improvement of 0.5 % to 1 % in comparison to conventional cylindrical blades.

In rear stages of HP & IP turbines and in few middle stages of the low-pressure turbine, profile losses due to improper incidence flow on the relatively long cylindrical blade are very high. Figure 4 shows the velocity diagram for a typical blade stage. The incident flow velocity to the moving blade changes due to the change in circumferential velocity at each blade section along the blade height.

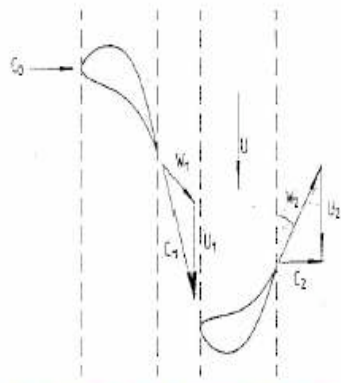


FIG. 4: X-SECTIONAL VIEW OF A TYPICAL CYLINDRICAL BLADE STAGE



FIG. 5: TWISTED BLADE WITH INTEGRAL SHROUD

This causes improper incident losses especially in longer blades. Minimisation of these losses calls for different inlet and outlet angles across the height of blade leading to application of blade with pronounced twist and narrower outer section of profile.

Blade of such type of construction is shown in figure 5. The use of various profiles of decreasing cross-section along the height significantly reduces profile losses. The incident and exhaust flow angles are better optimised and the blade can be made longer. The blades described here are equipped with T-roots and integral shrouds. Integral shrouds enable better sealing with the casing thus reducing tip clearance losses in such stages. These blades are installed without gaps at tip with neighboring blades. Root and shroud are provided with the special rhombohedral form which results in an elastic twisting of the blade on installation and ensures a closed, prestressed blade assembly, even in the transient operating range.

3. 3DV BLADING

Most of the turbine manufacturers now use three dimensional blade design but they still apply the same degree of reaction to all stages irrespective of being reaction or impulse blading. This constraint puts a limit to design when aiming for the highest efficiency. As three dimensional blade has to be designed for each individual stage and each particular application, the purpose of keeping same degree of reaction has lost its benefit. BHEL has now introduced new blading where in addition to three dimensional blade shape, the reaction of each stage is set individually varying between 10 and 60 %. This is being done with the help of a software called 3DV.

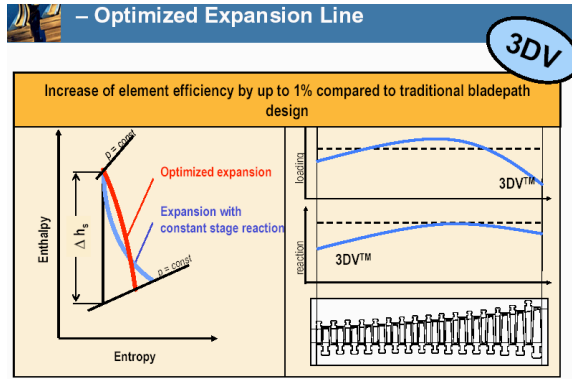


FIG.6

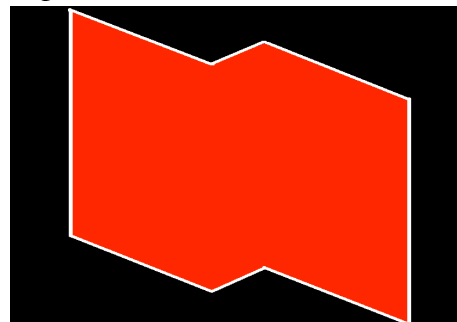
The use of numerical optimization methods has enabled BHEL to individually vary stage reaction and stage loading for every stage in order to obtain maximum efficiency. This allows efficiency to be increased by 1% as compared to blading with 50% reaction. Computer tools and 5-axis milling machines facilitates manufacturing of such complicated shapes of profiles. Thus a new generation of blading 3-dimensional variable reaction is here to further improve the efficiency of steam turbines.

5. NEW SHROUDS TYPE

BHEL has used new integral shrouds of blades to provide a good seal between the main steam flow and the flow at blade tips thereby enhancing the efficiency of blading, while at the same time providing extremely good damping behaviour to counteract excitation resulting from random fluctuations in steam flow and speed harmonics.



STEPPED SHROUD OF IP/LP BALDES



Z SHROUD OF LP BLADES



NORMAL SHROUD WITH HOLLOW

FIG.7

6. NEW SEALING TYPE

Seal related efficiency losses can be eliminated by introducing brush tip seals. Efficiency of turbine can be improved by using this brush tip seal which eliminates seal related efficiency losses with retractable brush packing.



FIG.8 BRUSH TIP SEALS

6. MANUFACTURING FACILITIES AT BHEL, HARDWAR

Elaborate and sophisticated manufacturing facilities have been available at BHEL, Hardwar plant for producing high quality, precision blades having complicated profiles and shapes. These facilities have been getting further augmented by establishing new shops equipped with numerous state-of-the-art CNC machining centers e.g. 5 axis milling machine to take care of the technological requirements for the new design of blades and achieve high quality of new generation precision blading. The new blade shop is capable of manufacturing complex geometry 3DS blades, twisted blades with integral shrouds, 3DV blades and TX profile blades of high quality surface finish.

7. CONCLUSION

Today designer has access to calculation methods, which very realistically represent the flow in a turbine. These flow calculation methods are used to optimise blade design from high pressure through to the low-pressure turbine. Three-dimensional blades are implemented in HP and IP turbines to reduce secondary flow (3DS blades). Twisted blades with integral shroud are used to reduce the incidence flow losses and further

increase efficiency. Highly efficient 3DV blading is being commercialized in BHEL manufactured sets recently.

The simulation of unsteady flow in the turbo-machinery is a challenging task and current researches are directed at CFD modeling to significantly improve aerodynamic performance of the blading.

REFERENCES

1. M. JANSEN, W. ULM

‘Modern Blade Design for Improving Steam Turbine Efficiency’ Siemens AG, VDI Berichte, 1995

2. H OEYNHAUSEN, A. DROSDZIOK and M. DECKERS.

‘Steam Turbine for the New Generation of Power Plant’ VGB Kraftwerkstechnik, 1996, No. 12, 890-895

