# Flow and Heat Transfer Characteristics of Ribbed Turbine Blade Cooling Channel: A Review

Ashish Kumar Kashyap[1], Vikky Kumhar[2], Ajay Kumar Verma[3]
[123]Department of Mechanical Engineering, SSTC-SSGI, Bhilai (C.G.) India.

**Abstract**

*The main objective of the study is to obtain high overall cooling performance with lowest possible penalty on thermodynamic performance cycle. The periodic ribs are frequently employed in various ducts to enhance the heat transfer process for many applications including gas turbine cooling systems. These arrangements of ribs and deflectors have important influence on the thermal and hydraulic performances of these cooling ducts. It is essential to understand the flow physics and to improve the current internal cooling design. Many techniques have been developed to enhance the heat transfer in these passages. The cooling passage located in the middle of the airfoil is often used with rib turbulator while pin fins and dimples can be used in the trailing edge portion of the vanes and blades.*

***Keywords**: Cooling Channel, Thermal Performance, Rib, Deflectors, Airfoil, CFD, Optimization.*

## I. Introduction

A recent trend in the gas turbine industry is to increase the thermal efficiency of the gas turbine. The efficiency requirements for gas turbines are increasing to reduce consumption of fossil fuels and CO2 emissions. One approach is to increase the turbine inlet temperature (TIT). However, the turbine blades are then exposed to higher gas stream temperatures and severe thermal conditions. Hence, complicated cooling technologies, such as rib-roughened serpentine cooling, impingement cooling, film cooling, and pin-fin cooling, have been adopted to reduce the surface temperatures of turbine blades, which requires complex coolant passage configurations inside the rotating blades as shown in Figure 1.1.

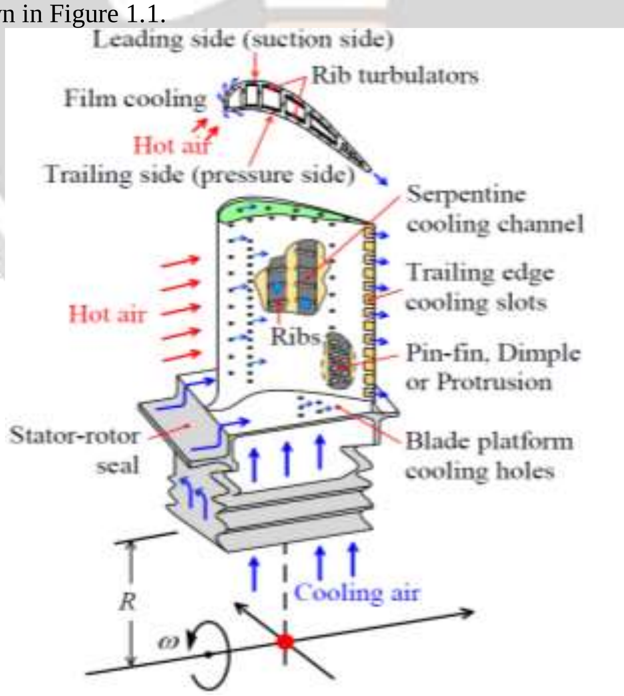


**Figure I.1 Modern gas turbine rotor blade with cooling passage network and the coordinate system defined [12]**

### 1.1 Turbine Cooling Basics

Although cooling is necessary, it affects the gas turbine operation inadvertently:

- The cooling air supplied to the blades and vanes is directly bled from the compressor. As a result, the mass of air going into the combustor is decreased.
- In order to incorporate the various structures like fins, cooling passages etc. the trailing edge thickness of the blades must be increased which adversely affects the aerodynamic performance of the blades

Various parts of the turbine blade are cooled using various techniques. The front part, called the leading edge, is generally cooled by impingement cooling. The middle part is generally cooled by using snake-like passages endowed with ribs along with local film cooling. The back part, called the trailing edge, is generally cooled by impingement and film cooling.

Depending on the size of the blades, the airfoil characteristics of the wind turbine defines the aerodynamic performance, amount of mechanical power of the rotor, and rigidity of the blade. It is important to understand the aerodynamic concepts of the airfoils to define the power production of the given wind turbine.

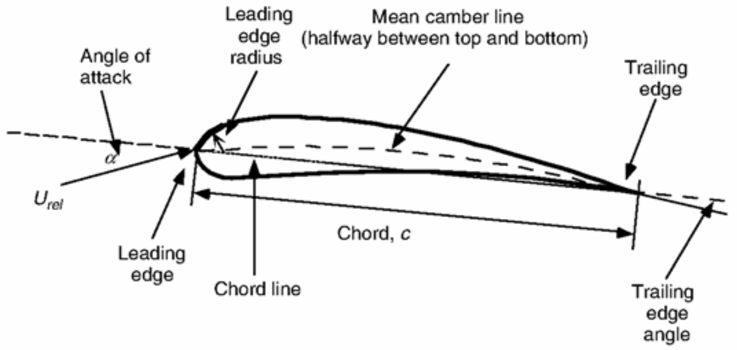


Figure I.2 Sketches of the typical airfoil

## II. Literature Review

In this chapter literatures have been carried out the briefly discussed in below before investigation.

**Launder and Iacovides (1995)** reviews current capabilities for predicting flow in the cooling passages and cavities of jet engines. Partly because of the need to enhance heat transfer coefficients, these flow domains entail complicated passage shapes where the flow is turbulent, strongly three-dimensional (3-D) and where flow separation and impingement, complicated by strong effects of rotation, pose severe challenges for the modeler. This flow complexity means that more elaborate models of turbulent transport are needed than in other areas of turbine flow analysis. The paper attempts to show that progress is being made, particularly in respect to the flow in serpentine blade-cooling passages.

**Siddique et al (2012)** explored the high inlet temperatures in a gas turbine lead to an increase in the thermal efficiency of the gas turbine. This results in the requirement of cooling of gas turbine blades/vanes. Internal cooling of the gas turbine blade/vanes with the help of two-pass channels is one of the effective methods to reduce the metal temperatures. In particular, the trailing edge of a turbine vane is a critical area, where effective cooling is required. The trailing edge can be modeled as a trapezoidal channel.

**Xie et al. (2013)** studied the flow structure and heat transfer enhancement in square ribbed channel with different positioned deflectors and found that the in all cases, Case D, in which the deflectors are positioned above and close to the ribs and the distance from the bottom wall is 20 mm, presents the most prominent effect on the heat transfer enhancement and thermal enhancement factor. In this study, the channel inlet Reynolds number ranges from 8,000 to 24,000. The influence of deflector arrangement on the overall performance characteristics of ribbed channels is investigated with six different cases; i.e., one case of an array of seven continuous ribs mounted on one wall and the other five cases with deflectors installed on side walls that are designed to determine the most optimal performance.

**Kalihari and Patel (2014)** has been re-examining for various researches on analysis of the turbine blade cooling using Experimental and Computation i.e. Computational Fluid Dynamics (CFD). During experiment wide range of flow model are used in order to check the performance of the model in terms of fluid flow and heat transfer and the place where lack of experimental setup is there Computational models where used and the experimental result are well compared and validated and new techniques are developed. Since

**Srinivasan and Kumar (2016)** studied a Computational fluid dynamics analysis of air and steam cooling a rectangular channel with parallel ribs. The effects of Reynolds numbers (Re), rib spacing ratio (P/e), and rib angles (α) on steam and air convective heat transfer were obtained. Heat transfer distribution is done for rib spacing ratio (P/e) =8, 10 and 12 and ribs angle 900 to 450.The heat transfer enhancement of both air and steam increased with decreasing the rib angle from 90° to 45°. Although both air and steam flow are similar to each other, the steam flow obtains a high convective heat transfer enhancement capability. For the corresponding degrees the heat transfer coefficient decreases and a study is made on rectangular duct having acute and right-angled ribs based on a backflow. Study is made on P/e = 8 having higher strength when compared with P/e = 12 is analyzed based on heat transfer of air and steam flow through a rectangular duct. The modelling has been done on the Creo parametric 2.0 software and to get the exact mesh of the duct the meshing was done in Hypermesh and the analysis were done in CFD Fluent software.

**Kumhar et al (2017)** investigated 3D CFD Analysis of a rotary engine blade cooling passage/duct during which the required domain subjected to vital load i.e. static likewise as dynamic load that is due rotary engine blade is operated at warm temperature and pressure which ends up in thermal stress and varies the blade performance. so as to avoid clastic failure of blade effective and economical cooling techniques ought to be enforced that ultimately leads to higher thermal potency and most power output. Intensive literature review is disbursed within the field regarding rotary engine blade cooling. This work thinks about with the rotary engine surface blade internal duct cooling conventionally and with the assistance of fluid and warmth transfer round the duct surface is been analysed and also the performance is foreseen with the assistance of Finite component volume tool ANSYS- Fluent, wherever simulation is being done. The goal is to hold out heat transfer constant at the rotary engine blade internal duct surface exploitation completely different turbulent model likewise as comparative case study is additionally been bestowed. The FEV results area unit valid with well to literature.

**Regionviat (2017)** studied the gas turbines are extensively used for air craft propulsion, land-based power generation and industrial applications. Thermal efficiency of gas turbine improved by increasing turbine rotor inlet temperature. The current rotor inlet temperature in advanced gas turbine is for above the melting point of blade material. A sophisticated cooling scheme must be developed for continuous safe operation of gas turbines with high performance. Gas turbines are cooled externally and internally. Several methods have been suggested for the cooling of blades and vanes.

**Kaewchoothong et al (2018)** studied the flow and heat transfer characteristics in a rotating serpentine passage with ribbed walls. The channel length-to-hydraulic diameter ratio of the rotating serpentine passage (L/Dh), the rib height-to-hydraulic diameter ratio (e/Dh), rib angle of attack, the rib pitch-to-height (p/e) ratio and aspect ratio (AR) were fixed at 11.33, 0.13, 90°, 10 and 1, respectively. Numerical simulations were performed at a constant Reynolds number, Re = 10000. The rotation number ($R_o$) levels were 0.0, 0.1, 0.2 and 0.3. The distribution of local heat transfer coefficients and the flow field in a rotating serpentine channel were studied by numerical simulations using the commercial software ANSYS ver.15.0 (Fluent).

**Ravi et al. (2017)** studied the heat transfer and friction characteristics of four different rib geometries 45°-shaped, V-shaped, W-shaped and M-shaped ribs in a two-pass stationary channel have been numerically investigated. The aspect ratio (Height to Width) of the cooling channel was 1:1 (square). The Reynolds number was varied from 20,000 to 70,000. For the computations, the Reynolds averaged Naviere Stokes (RANS) equations were solved with the commercial software ANSYS Fluent using the realizable version of k-ε (RKE) model. On comparing the overall thermal hydraulic performance, he found the V-shaped were observed to perform significantly better than 45°-shaped, W-shaped and M-shaped ribs.

**Bacci et al (2017)** estimated of metal temperature is paramount to ensure an adequate life span of gas turbine hot gas path components. An experimental campaign was carried to investigate pressure loading and metal temperature distribution of an industrial blade cooled by means of straight smooth channels. Changing mainstream and coolant mass flow rates it was thus possible to characterize the thermal response at different operating conditions. CFD simulations allowed to relate the metal temperature distribution to the processes of laminarization and transition of the boundary layer.

## III. Conclusion

Gas turbines play a vital role in today's industrial environment. As the demand for power and energy increases, improvement in power output and thermal efficiency of gas turbine is essential, this can be achieved by efficient cooling methods. The cooling of gas turbine components using internal convective flow of a single-phase gas has been used for last 50 years; from simple smooth cooling passage to very complex geometries involving many different surfaces, architectures and fluid-surface interaction. The main objective of the study is to obtain high overall cooling performance with lowest possible penalty on thermodynamic performance cycle. The periodic ribs are frequently employed in various ducts to enhance the heat transfer process for many applications including gas turbine cooling systems and compact heat exchangers.

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