Review of Cooling of Gas Turbine Blades

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Abstract:
There are various sources of power generation, but gas turbine plays an important role in power generation. Gas turbines are widely used in land based power generation, aerospace sector and industrial purposes and several purposes. Gas turbines are operated at very high temperature up to 1400-1500°C which ultimately leads to melting temperature of turbine blade and there is possibility of failure of gas turbine hence a sophisticated system should be provided for cooling of gas turbine blade and also for increasing efficiency the inlet temperature of gas turbine blade should be increased .But due to high temperature it will directly affect on turbine blades. There are several methods of cooling of gas turbine blades this are useful for cooling of gas turbine blade. This methods are improve the performance of gas turbine by reducing temperature of turbine blades. The blades are made of super alloys for sustaining high temperature. The various software are used for detecting capacities of working at high temperature without failure. Generally ansys cfd software fluent is used for analysis of gas turbine blades. various material analysis also taken as consideration for sustaining high temperature. various mixture of alloys can held high temperature hence this are widely used for manufacturing of turbine blade. By using various cooling system turbine blade temperature can be decreased up to 200 °C or more. Cooling system mostly uses air as coolant which is impinged on turbine blades and it leads to much reduced temperature of gas turbine blade.

Keywords: leading edge, cascade, external cooling, inlet fogging, finite element analysis

Introduction
Gas turbine play an important role in power generation. Gas turbines are extensively used in various power generation sources but the efficiency of gas turbine can be increased by increasing inlet temperature of rotor of gas turbine which is adversely effect on blades of gas turbine. Thermal efficiency and power output can be increased by increase in inlet temperature. But high temperature causes failure of gas turbine blade. The inlet temperature of advanced gas turbine are relatively close to the melting point of gas turbine blade. The high temperature causes thermal corrosion which ultimately turns into destruction of blade, if blade exceed temperature there is more chances of thermal failure of gas turbine blade which ultimately affect on whole gas turbine failure hence a sophisticated system is provided for cooling of gas turbine blade. It is necessary to cool the high temperature blade because it produces thermal stresses on the blade and due to high temperature there is possibility of corrosion of blades. So a various cooling systems are provided on gas turbine. Also various analysis are also held on blade so it can sustain high temperature. the blades are made of nickel chromium super alloys for sustaining high temperature of advanced gas turbines. The following four types of cooling methods have been adapted to varying degree of success.

- Convection cooling
- Film cooling
- Transpiration cooling
- Impingement cooling

The blade failure occur due to thermal cracking and thermal corrosion of blade due to high temperature. although super alloys are used but they does not sustain high temperature in advanced gas turbines so a sophisticated cooling system should be provided to lower the temperature of blade. advanced gas turbine operate at very high temperature hence it is impractical to perform experiments to analyze the blades due to higher cost and several reasons. software modeling of the blade helps to analyze the blade properties and it's performance of gas turbine. there are three types of modeling are done that are structural, thermal and fluid dynamics by the ansys and fluent software. the thermal analysis of gas turbine blade is done by ansys, which perhaps show the temperature distribution on the vane and also it helps to evaluate the heat transfer at various places By taking various experiments the several conclusion are made on the blades by passing cool air through it and also it results in increase in efficiency of gas turbines. several experiment are done on the blade for increasing its performance. The gas turbine performance improves with cooling of blades due to it's low thermodynamic performance, the turbine blade have high temperature so there is possibility of thermal corrosion and cracking of blade so the blade has to posses property that it
can resist temperature with corrosion resistance. Various fluid dynamic forces are acting on it so its shape as well as temperature distribution should be determined. But it is economical to analyse on the blade actually. So various software like ansys, fluent are used also the material are used as per consideration. Cooling arrangement is very helpful to to raise the life of turbine.

**Nomenclature**

<table>
<thead>
<tr>
<th>Nickel155</th>
<th>Nickel alloy</th>
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<tr>
<td>Iac</td>
<td>Inlet air cooling</td>
</tr>
<tr>
<td>mc/mg</td>
<td>Ratio of mass of coolant to gas</td>
</tr>
<tr>
<td>Nu</td>
<td>Nusselt number</td>
</tr>
<tr>
<td>kj/kg</td>
<td>Latent heat of evaporation unit</td>
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<tr>
<td>temp</td>
<td>Temperature</td>
</tr>
<tr>
<td>Rh</td>
<td>Relative humidity</td>
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<tr>
<td>cpr</td>
<td>Cycle pressure ratio</td>
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<tr>
<td>cfd</td>
<td>Computational fluid dynamics</td>
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**Principle**:

Generally gas turbine works on principle of brayton cycle. Gas turbine engine derive the power from burning fuel in combustion chamber and using the fast flowing combustion gases to derive a turbine in much the same way as high pressure steam derives the steam to steam turbine.

**Working**:

In gas turbine the compressed air is mixed with fuel and burned under constant pressure conditions. The resulting hot gas is allowed to expand through a turbine perform work. Fresh atmospheric air flows through compressor that brings to higher pressure. Energy is then added by spraying fuel into the air and igniting it so the combustion generates high temperature flow. It consist of three parts a compressor, combustor and turbine.

**Problem statement**:

With increase in temperature of gases, the heat is transferred to the blades will increase appreciably resulting in thermal failure. With existing material, it is impossible to go for high temperature. Due to some condition it is necessary to provide cooling arrangement for turbine blade to avoid blade failure. So a cooling system is important in aspect of its working conditions.

**Literature survey**

In this present work of fathimunnisa begum, dr. v. v. ramareddy, s. ramanjaneyulu they have done analysis on turbine blade the blade is carried out on ansys software also cooling arrangement are analyzed which directly affect efficiency [1]. The blade has aerofoil shape so by using catia software the blade model is made. And it is analyzed for high temperature.. the figure shows temperature distribution with two different models this are chromium steel and nickel155.the thermal and structural analysis is done on ansys software. The fluid dynamics analysis is done using cfd software fluent. The temperature is considered about 1200-1500°C. also the using finite element analysis method the blade is analysed with drilled radial holes the temperature and heat transfer is plotted on the graph with respect to number of holes with cooling of gas turbine blade. this graphs are shown below.

![Fig.1 distribution of temperature around the surface of blade without holes [1]](image1)

![Fig. 2 total heat transfer Vs No. of holes [1]](image2)
They have used two medias which are steam and air that are decreasing the temperature of gas turbine blade. A. b. Moskalenko, a. i. Kozhevnikova done analysis on heat transfer between coolant and blade [2]. By varying the coolant temperature what it affect on blade temperature that can be determined also which coolant gives more effectively is can be concluded by the graph. In brief about is described is here. They have predicted efficiency of turbine after blade cooling. Fluid dynamics is calculated by cfd fluent software. It accounts conventional heat transfer through which it is measured with the help of coefficient of heat transfer of air average temperature of gas turbine bladed cooling by air. It is resulted that having low pressure gives the values of heat transfer coefficients as required. The efficiency of gas turbine by using cooling mediums depends on heat transfer coefficient and average volume temperature of blade from coolant pressure. It is predicted that for two coolants that are steam and air. They are depends on pressure of cooling medium. Pressure of cooling medium is directly proportional to heat transfer coefficients. It is also estimated about the relationship between cooling temperature and efficiency of gas turbine. The blade temperature and coolant temperature is shown.

Jet impingement is used for high temperature loads. Effective heat transfer is by convection method and it depends on nusselt number. Abdullah R. Al Ali, Isam Janajreh has determined the nusselt number by numerical model. It is considered with model having same distribution of temperature and thermal stress [4]. And it is resulted as below they have concluded that jet impingement have more effective where temperature of blade is high by numerical simulation. They found out the Nu number which is useful for finding heat transfer coefficient. Whichever increase the thermal efficiency of turbines by blade cooling by impingement of jet. Heat flux around the blade is calculated by them also they have predicted that as reduction in average blade surface temperature there is significant improvement in efficiency due to turbine blade jet cooling [4]. Generally Impingement of jet is used for high loads. Hence it is extensively used for high temperature blade cooling.

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There are many techniques of cooling of gas turbine blade but film cooling is most effective technique. It is mainly
happened by convection heat transfer so Kenichirotakeishi, SunaoAoki, TomohikoSato has proposed the principle and working of film cooling as follows. They have concluded that film cooling has most effective cooling which is extensively used. They have predicted that influence of film cooling on rotating blade having cascade geometry is by nozzle wakes. Film cooling has thin film form on blades. Leading edge has most effectiveness of film cooling for rotating blade. The effectiveness of blade cooling for stationary blade is by nozzle wakes. They have concluded that film cooling effectiveness is less due to pressure which mixes the film at the surfaces due to radial flows and mixing with steam. But film cooling has more influence on cooling of gas turbine blade[5].

The experimental work of AnoopKumarShukla, OnkarSinghis on gas turbine cycle with various methods such as film cooling, steam injection etc. The present studies conclude that the efficiency and power output can be increased by combining this methods. They have studied and concluded about parameters affecting execution of injection for cooling of blade by using a process of vapor absorption inlet air cooling. Film cooling is used for cooling of gas turbine blade. The inlet temperature how about the efficiency and power output increases. They have predicted about the efficiency and also how steam injection influences on cooling of gas turbine blade. The schematic of steam injected gas turbine combined cycle with vapor absorption cooling system[6]. Overall study is on how the cooling effect is produced by film cooling and steam injection they have shown the relationship between efficiency and specific work and they have predicted that cooling effects on both efficiency and specific work both increases.

The geometry of turbine blade affect the cooling of gas turbine blade. A. Guelailia, A. Khorsi, M.K. Hamidou they have derived the various geometry and its effect on performance of gas turbine blade. They have predicted about leading edge cooling by its geometry[8]. These cooling effect give high performance of gas turbines. Generally leading edge has maximum temperature hence it should be cooled very fast. This is very important to cool the leading edge to avoid failure of blades so by varying the geometry of blade and analysis of blade by ansys software it is resulted that edge film cooling is more effective. Heat transfer for both blades of holes give more cooling effectiveness they have resulted the about the numerically how the film cooling improve the performance of gas turbines. There are various methods of cooling of gas turbine blade but integration of all this methods is very effective so Je-ChinHan has integrated all the methods and prepared model of blade. This model contain all possible methods of cooling of gas turbine blade. Mainly there are three methods of cooling this are film cooling, impingement cooling, and internal cooling methods. It is very important to use combination of this methods because this are help us to giving much cooling effect. They have concluded about the cooling of gas turbine blade by various methods. The internal and external cooling both are used there effectiveness has been predicted. They concluded that the turbine edge should be cooled very that is problem of new generation turbines blades. The heat transfer by cooling...
medium at edge is so needed because it gain high temperature and possibility of failure. It should be cool leading edge at faster rate. So they have predicted about the coolant passage because cooling passage effects on cooling of blade by its geometry coolant flow on blades of turbine. They have predicted that various coolant passages of cross section such as square, triangular, trapezoidal etc. are very useful for cooling[8]. The various methods of cooling both external and internal are shown in figure.

Among all the techniques film cooling is most effective that has been proved but it is not affect all the parts of blade. Film cooling has several types. In gas turbine blade the high temperature is first attained by the leading edge due to direct bombardment of gases and continues contact with gases so it important to cool the leading edge as soon as possible in film cooling there are various methods so it is also important to use to appropriate method of film cooling. J.h.liu, y. b. liu, l.liu has considered all the methods of film cooling and discussed the suitable method for cooling purpose. It is resulted that the film cooling is mostly used for cooling of gas turbine blade with using drilled radial holes[10], by using numerical simulation it is found that temperature distribution is spread around the vane is constant. the blade model is taken with two criteria this are considering with solid heat transfer and without solid heat transfer by the technique of conjugate heat transfer method. the heat transfer is mostly occur at the gap between lines of holes or space between two successive rows of radial holes mainly by conduction. among all of the film cooling stable layer is only formed in showerhead film cooling. in this the modeling of vane is done by enwall film cooling & it can be concluded that it is better film cooling technique.

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Results and discussion

- Principle of film cooling is convection heat transfer. As heat is directly transferred from blade to coolant.
- In film cooling due to convection there is higher cooling effects is produced. Drilled holes are very useful for reducing temperature as well as heat transfer of gas turbine blade.
- Steam has higher convective heat transfer so it resulted that it is most effective coolant it gives satisfactorily result for heat transfer and lowering the temperature of blade.
- The thermal efficiency mainly depends on cooling system because it is directly affected by cooling system so it can be say that performance of turbine depend on it.
- Heat dissipation is depend on two types convection and conduction in which heat transfer coefficient and conductivity play important role for heat dissipation respectively. Heat transfer coefficient is very important for heat transfer and cooling purpose. It has to be taken as coolant have high heat transfer coefficient.
- Impingement cooling is mostly used for high heat loads. It is observed that maximum temperature is attained at the leading edge of the blade. So external cooling is also very helpful for cooing if gas turbine blade.
- There are various methods of film cooling in this appropriate is used as per there need.
- With increase in number of holes there is variation of temperature distribution and it produce much cooling effect
- Thermal efficiency and power output both increases much more due to cooling of gas turbine blade by using steam injection. about 60% efficiency has been got by using the cooling techniques.
- Performance of simple gas turbine increases by using various cooling techniques mainly film cooling.

Fig. 9 Combination of Cooling Technique The Schematic Of Modern Gas Turbine Blade [9]

Fig. 10 Schematic of film cooling concept blade model [10]
Conclusion

Thermal efficiency of gas turbines depends upon the inlet temperature. As temperature increases, the efficiency also increases. It is also resulted that film cooling is most effective technique of cooling of gas turbine blade. The thermal stress is developed on overall the blade due to high temperature so a cooling media should be properly used. The two cooling medium used are effective in which steam give more satisfactorily cooling effects. Drilled holes have high heat dissipation and decrease the temperature of blades, as number of holes increases heat transfer rate increases. It is predicted that for 13 number of holes it give much better results. It is concluded that inlet fogging helps to decrease the temperature of blade which is very useful for cooling for gas turbine power cycle as compared to other techniques. Cooling helps to reduce the temperature of gas turbine blade by combination of inlet fogging, film cooling and steam injection. It gives higher performance. Thermal efficiency and specific work output can be improved by injection of steam in combustion chamber. Film cooling uses principle of convection in which low temperature coolant forms thin film over surface which extracts the heat and cooling effect is produced which has more effectiveness. It can be concluded that there are different methods in film cooling but Endwall film cooling is also much used for cooling of turbine blade. After turbine blades have been cooled, one experiences not only an improvement in the capabilities of the engine but also an extension in the life of the engine.

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