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A study about Gas Turbine on Improving Performance and Life

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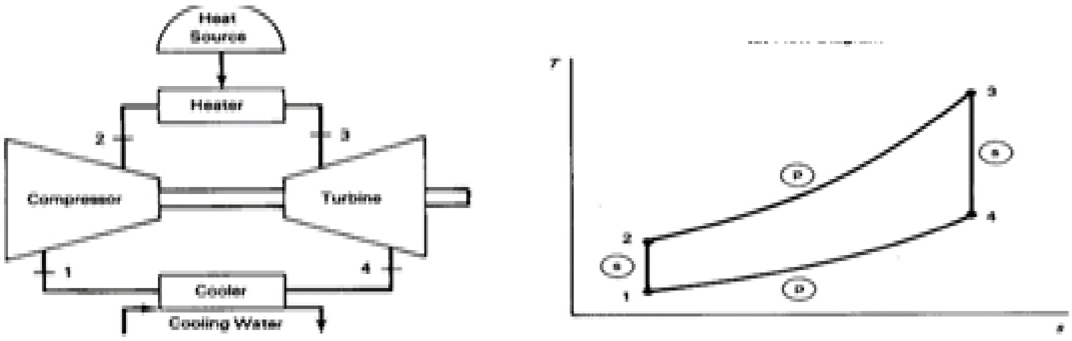
ABSTRACT- Optimizing gas turbine performance is a key consideration for designers. Such activity returns divided of improved output, heat rate recovery, equipment life cycle, maintenance cost etc. In this review paper observe various performance parameter of gas turbine, such as change in different parameters like change in inlet temperature and pressure, relative humidity, inlet type of fuel, Change in cooling effect and change in material. With the help of that effects designer canincrease the performance of gas turbine as increase efficiency.

***KEY WORDS:** Gas turbine blade, Compressor stator blade, Tip leakage flow, cooling, Exhaust gas recirculation.*

I. INTRODUCTION

The basic operation of the gas turbine is similar to that of the steam power plant except that air is used instead of water. Fresh atmospheric air flows through a compressor that brings it to higher pressure. Energy is then added by spraying fuel into the air and igniting it so the combustion generates a high-temperature flow. This high-temperature high-pressure gas enters a turbine, where it expands down to the exhaust pressure, producing a shaft work output in the process. The turbine shaft work is used to drive the compressor and other devices such as an electric generator that may be coupled to the shaft. The energy that is not used for shaft work comes out in the exhaust gases.In the gas turbine, there is a continuous flow of the working fluid.This working fluid is initially compressed in the compressor. It is then heated in the combustion chamber. Finally, it goes through the turbine.The turbine converts the energy of the gas into mechanical work. Part of this work is used to drive the compressor. The remaining part is known as the net-work of the gas turbine.



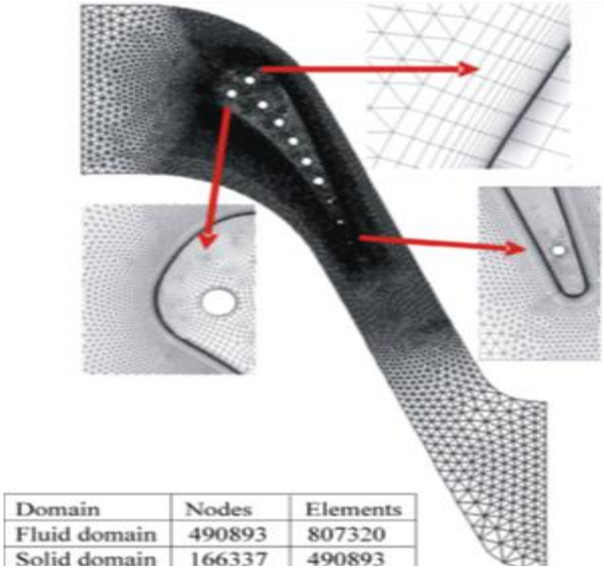
(a) Flow diagram (b) Temperature Entropy Diagram

Fig.1 The basic gas turbine cycle

CURRENT SCENARIO OF GAS TURBINE [1]

The overall operating cost of the modern gas turbines is greatly influenced by the durability of hot section components operating at high temperatures. In turbine operating conditions, some defects may occur which can decrease hot section life. Methods used for calculating blade temperature and life are demonstrated and validated. Using these methods, a set of sensitivity analyses on the parameters affecting temperature and life of a high pressure, high temperature turbine first stage blade is carried out. Investigated uncertainties are:(1)blade coating thickness,(2) coolant inletpressureand temperature (as a resultofsecondaryairsystem), and (3) gas turbineloadvariation.

The coolant vanes are placed into the blades for the cooling purpose.In addition, considering inlet cooling temperature and pressure, deviation in temperature has greater effect on blade life.



Domain	Nodes	Elements
Fluid domain	490893	807320
Solid domain	166337	490893

Fig. 2View of numerical mesh on plane of constant span-wise coordinates[3]

The life estimation graph is shown in figure 3.

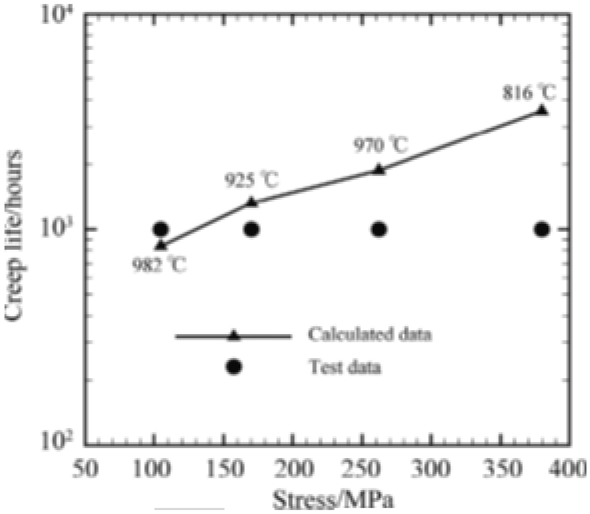


Fig. 3 Comparison between calculated and test data for creep life model validation.[3]

Results show that increasing thermal barrier coating thickness by 3 times, leads to rise in the blade life by 9 times. In addition, considering inlet cooling temperature and pressure, deviation in temperature has greater effect on blade life. One of the interesting points that can be realized from the results is that 300 hours operation at 70% load can be equal to one hour operation at base load.

Failure Analysis of a Compressor Blade [5]

The stage II compressor stator blade of a developmental gas turbine engine was found damaged during dismantling of the engine after test run. A portion of the blade was found fractured from the hub region at leading edge. A crack was also observed extending from the fractured surface towards the centre of the airfoil region of the blade. Low magnification stereobinocular observation revealed presence of beach marks on the fractured surface indicating the blade failure in progressive mode. This observation was further confirmed by scanning electron microscopy. The crack origin was at the blade hub-stem junction on the leading edge side. Presence of machining/filing marks appeared to be the reason for the fatigue crack initiation from this region. No metallurgical abnormalities were present at the crack origin. However, deep filing/machining lines were observed at the stem region of the blade attributing to the cause of failure.

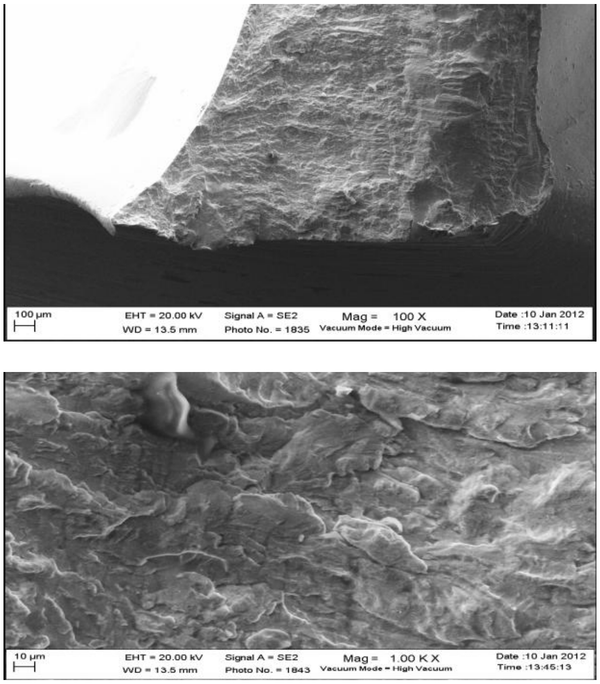


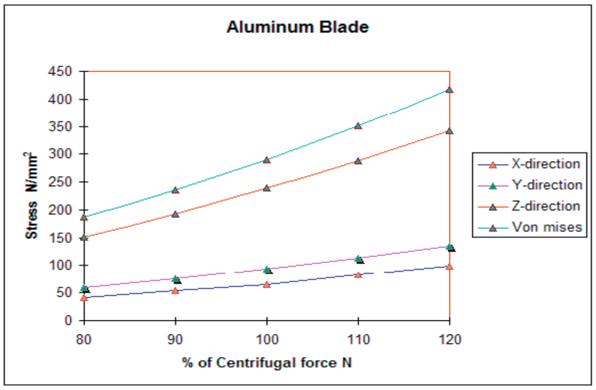
Fig. 4SEM fractograph revealing presence of oxide layer and vaguely delineated striations near the crack origin [5]

Optimum material evaluation for gas turbine blade using ReverseEngineering (RE) and FEA[2]

Gas turbines play a major role in the field of aviation owing to their high power to weight ratio and being self-contained, as compared to other conventional power generating units.

Reverse engineering process involves sensing the geometry of existing part, creating a geometric model of the part from the sensed data and passing this model to an appropriate CAD/CAM system for manufacturing. They deals with the modelling and analysis of gas turbine blades. The design data for a turbine blade is obtained using Reverse Engineering technique. Using the data so obtained, a model of the turbine blade is created in ANSYSFEA package. For the given loading conditions, the blade is analysed for static structural analysis for different materials at varying centrifugal loads and different materials and a safe and feasible material is suggested

Blade Stresses in different materials due to varying centrifugal force is shown in figure 5.



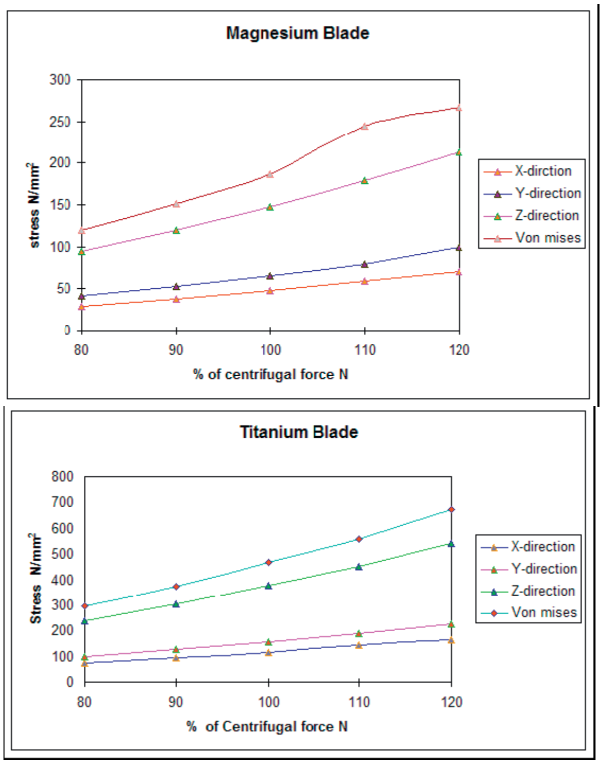


Fig.5Stresses in 3 different blades due to varying centrifugal force[2]

It can be seen from Figure 5 that the Al blade stresses are below the yield strength of the material even after
Increasing the centrifugal force by 10% of normal value. However, the von Mises stress exceeds the yield strength beyond a 20% increase of normal value. The yield strength of Mg is 250 MPa. It is noted that the stresses in Mg blade reach the yield limit at about the 120% value of the centrifugal force. It is noted from the bottom figure which relates to the Ti blade performance that the von Mises stress in Ti blade is within the yield strength when increasing the centrifugal force beyond 20% of normal value.

Aerothermodynamics of tight rotor tip clearance flows in high-speedunshrouded turbines[1]

The inevitable clearance between stationary and rotating parts in any fluid machinery gives rise to leakage flows, which strongly affect the overall performance of the machine. In modern gas turbine engines, the existing gap between the rotor air foil tip and the shroud is responsible for about one third ofthe total aerodynamic losses. Additionally, this leakage flow induces fierce unsteady heat loads onto the rotor casing and provokes significant thermal stresses at the air foil tip. One can attempt to curtail these detrimental effects by running tight clearances; however, the meagre number of publications on this topic presents an obstacle to exploiting the design opportunities.

The outcome of an extensive numerical investigation of a high pressure turbinestage operating at engine-representative non-dimensional parameters (Reynolds and Mach number, temperature ratios). RANS calculations were performed using the Numeca FINE/Turbo suite, adopting the k-w SST turbulence model to investigate the aerodynamic and heat transfer characteristics in the tip region. Five clearances, ranging from 0.1% to 1.9% of the rotor channel height, were simulated at adiabatic and isothermal (Ttotal,in/Tw = 1.57) conditions. The detailed flow analysis revealed an unexpected aerodynamic flow topology at tight clearances (h/H < 0.5%), characterized by a reverse flow over a significant part of the tip gap region. The heat transfer on the airfoil tip, shroud and near-tip regions was examined in detail, with emphasis on the different driving phenomena. This elaborate numerical study provides a deeper insight into the complex aerothermal physics of leakage flows occurring for tight clearances in a high-speed environment relevant to any fluid machinery design and analysis.

Comparing the last row with the second one shows a remarkable similarity of the temperature field, both in terms of magnitude as well as in the topology. This justifies that, even though different velocities (i.e. the absolute and relative) should be used to evaluate this viscous term in both of the reference frames, the importance of the viscous contribution surpasses the effect of the pressure gradient for tight clearances.

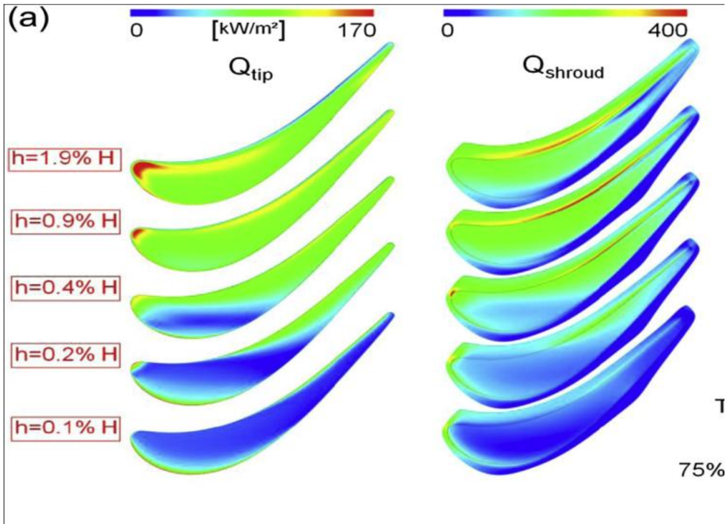


Fig. 6heat flux to the tip, shroud, and upper part of the blade suction side (75%-100% of blade height) [1]

Impact of Fuels on Performance and Efficiency of GasTurbine Power Plants[4]:

The work includes the effect of relative humidity, ambient inlet air temperature and types of fuels on gas turbine plants. Investigation also covers economic analysis and effect of fuels on emissions. Gas turbine frames of various ratings are used in gas turbine power plants in Saudi Arabia. 70 MWe GE-6101FA and 40 MWeGE-6561B frames are selected for the present study. GT PRO software has been used for carrying out the analysis including; net plant output and net efficiency, break even electricity price, break even fuel LHV price, carbon emissions etc., for a givenlocation of Saudi Arabia. The relative humidity and ambient inlet air temperature have been varied from 30 to 45 % and from 80 to 100° F, respectively. Fuels considered are natural gas, diesel and heavy bunker oil. Simulated gas turbine plant output from GT PRO has been validated against an existing gas turbine plant output. It has been observed the simulated plant output is less than the existing gas turbine plant output by 5%. Results show that variation of relative humidity does not affect the gas turbine performance appreciably for all types of fuels. For 70 MWe frame, for a decrease of ambient inlet air temperature by 10 °F, plant net output and efficiency have been found to increase by about 5 and 2 %, respectively for all fuels.

More specifically, plant net output and efficiency for natural gas are higher as compare to other fuels. For given 70 and 40 MWeframes, break even fuel price and electricity price have been found to vary from 2.03 to 2.54 US$/MMBTU and from 0.021 to 0.0254 US$/kWh respectively. It has been noticed that turbines operating on natural gas emit less carbon relatively as compared to other fuels.

Effect of humidity on net plant output is shown for different material in figure 7(a) and 7(b).

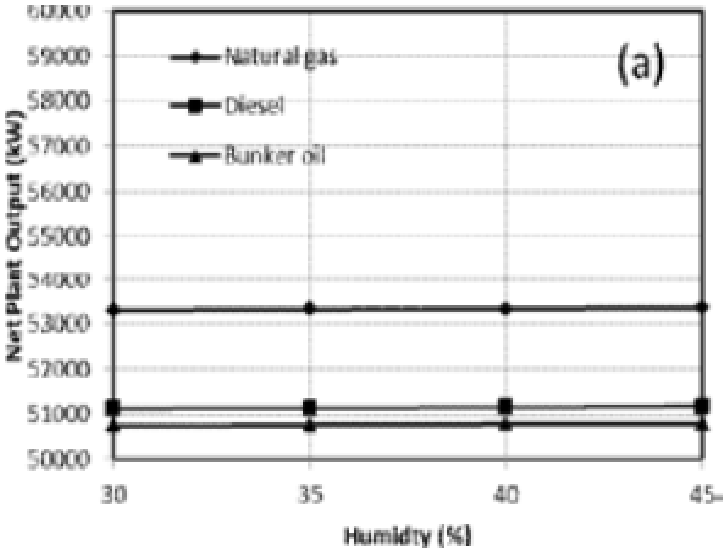


Fig. 7(a) Effect of humidity on net plant output for material GE 70MWe GE6101FA[4]

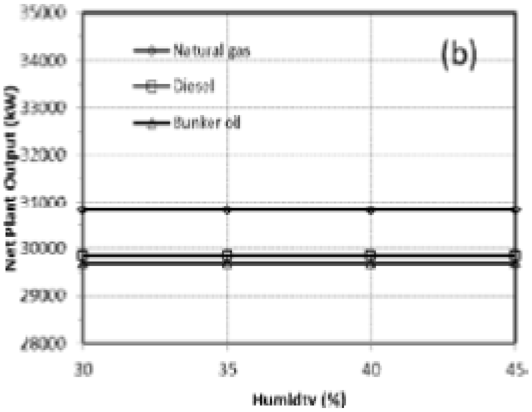


Fig 7(b) Effect of humidity on net plant output for material GE 40 MWeGE6561B,[4]

The effect of humidity on net plant output (for a given inlet air temperature 100 °F, for all Fuels, forthe above gas turbine frames) is shown in Fig. 2. RH has been varied between 30- 45% (this cover the prevailing average RH range in Saudi Arabia). It can be noticed that variation of RH does not affect/improve the performance appreciably. This observation is in agreement with an earlier study [3]. Since, RH does not have much effect on the gas turbine plant performance; it has been fixed at 30% in the present study.

Now, theeffect of ambient inlet air temperature on plant net output& efficiency (for a given RH of 30 %, different Fuels) is shown in Fig. 8

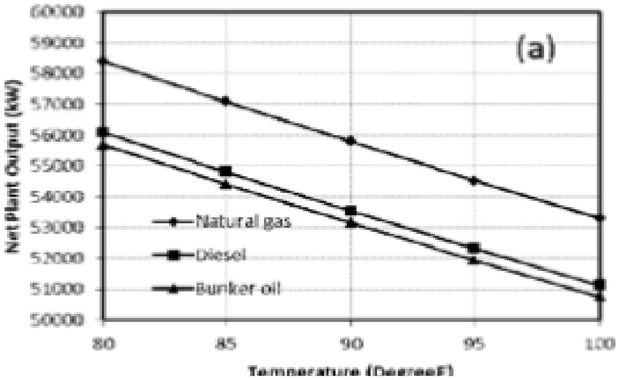


Fig. 8(a) Effect oftemperature on net plant output for material GE 70 MWe GE6101FA[4]

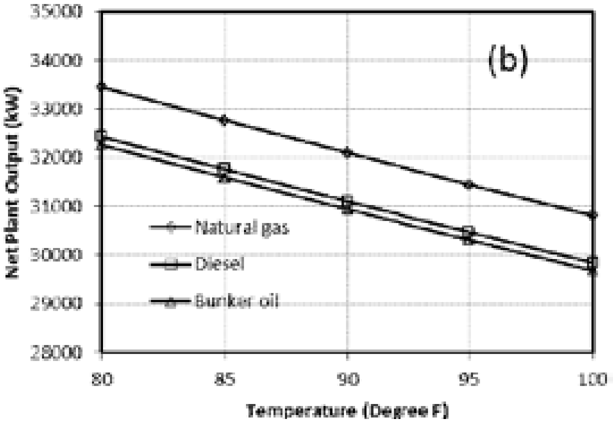


Fig. 8(b)Effect of temperature on net plant output for material GE 40 MWeGE6561B [4]

The effect of ambient inlet air temperature on plant net output& efficiency (for a given RH of 30 %, different Fuels) is shown in Fig. 8(a) and Fig. 8(b) for 70 and 40 MWe gas turbine frames, respectively.

II. CONCLUSION

The current status and parameter affecting gas turbine are reviewed here

1. Heat transfer and life through typical turbine blade are predicted and the computational results are fully analyzed. The heat transfer results show that maximum blade temperature at the reference case is 960°C and because of inlet temperature radial pattern, occurs at 70% span of blade leading edge.
2. The life estimation results demonstrate that the minimum life occurs at the samepoint as maximumtemperature.Thisindicatesthatthemost dominant factorforbladecreeplifeis temperature.
3. Theweakestpointforfatiguefailuremechanismisthe fir-tree region oftheblade.
4. Adding 300 mm TBC coating on the blade leads to 9 times increase in life in comparison with the reference case (100 mm TBC).
5. The machining/filing marks are to be avoided as they raise the local stress concentration level and can lead to fatigue failure. Therefore, sufficient care to be exercised to avoid usage of blades containing such notches /abrasion marks.
6. Titanium is best material for gas turbine blades for the centrifugal forces considered in this study as it possesses outstanding properties of structural stability when exposed to varying temperature and fatigue loads, and also possesses maximum strength at high temperatures.
7. The aerodynamic (adiabatic) efficiency proved to be mainly driven by the leakage mass flow and was predicted accurately from isothermal calculations with an errorlower than 0.17%. The results showed a novel change in the aero thermal characteristics in the over tip region for tight clearances and provide new physical insights, indispensable to design efficient rotating machines adopting small leakage paths.
8. Variation of RH does not improve the gas turbine performance for all types of fuels. For a decrease of ambient inlet air temperature by 10 °F, plant net output and efficiency have been found to increase by 5 and 2 %, respectively for the fuels considered in the study.
9. The plant net output and efficiency increase with decrease in ambient inlet air temperature. This can be attributed to the fact that with decrease in ambient inlet air temperature, air density and air mass flow increase.

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