International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 05 | May 2020 www.irjet.net p-ISSN: 2395-0072

Comparative Study of Different Turbine Blade Materials

Rushikesh Misar[1], Prajwal Poharkar[2], Suraj Thakare[3], Dr. Sachin Bhalerao[4]

[1]RushikeshMisar: Student, Dept. of Mechanical Engineering, JDIET College Yavatmal, Maharashtra, India
[2]Prajwal Poharkar: Student, Dept. of Mechanical Engineering, JDIET College Yavatmal, Maharashtra, India
[3]Suraj Thakare: Student, Dept. of Mechanical Engineering, JDIET College Yavatmal, Maharashtra, India
[4]Dr. Sachin Bhalerao: Professor, Dept. of Mechanical Engineering, JDIET College Yavatmal, Maharashtra, India

---***---

Abstract -*Basic structure of Gas Turbine Blade is too complex in terms of design. Also, the material used to manufacture the blade plays important role in heat transfer. There are several materials used for GT Blade which can withstand on high elevated temperature. But while working on high temperature blade fails prior to its designed life. The main reason of failure is high working temperature and stresses which are induced in the blade profile. Hence the structural and thermal stability of GT blade is required.*

There are several techniques are available to give thermal and structural stability to the GT Blade, like cooling technique, Blade profile hardening technique etc. But there is more need to understand the exact reason of failure of GT Blade and its causes. Hence the structural and thermal analysis of the blade material is important. By performing both analyses, we can understand the reasons of failure and remedies can be planed accordingly.

In this paper the thermal analysis of GT blade is carried out by choosing different materials like Stainless Steel Alloys, titanium based Alloys and Aluminum Based Alloys metals. For this purpose, CATIA V5R19 and ANSYS 14.5 software tools are used. The results obtained are studied closely and failures are noted with different metals and alloys. Best metal is concluded on the basis of both structural and thermal analysis results.

***Key Words*: GT Blade, High Elevated Temperature, Structural and Thermal Analysis.**

1. Introduction to GT Blade Materials

As GT blade works in very harsh environment and high temperature, material used to manufacture GT blade must be able to withstand on high pressure and temperature. It should work properly without losing its physical properties on temperature nearer to the melting temperature. Also it should maintain the blade profile. Continuous impingement of heat and pressure may affect the blade profile. But by providing proper cooling technique, failure of GT blade can be avoided. There are several metals are used for manufacturing of GT blade. Out of them Stainless steel alloys, Titanium, Inconel based alloys, Nickel Based Super-alloys are most popular.

1.1 Stainless Steel Alloy

In spite of this there is a group of iron-base alloys, the iron-chromium-nickel alloys known as stainless steels, which do not rust in sea water, are resistant to concentrated acids and which do not scale at temperatures up to 1100°C. It is this largely unique universal usefulness, in combination with good mechanical properties and manufacturing characteristics, which gives the stainless steels their raison d'être and makes them an indispensable tool for the designer.

1.2 Titanium Alloy

Titanium has a density of 4.5g/cm3 which is higher than aluminium, but lower than nickel and steel alloys. Titanium is stable to 8820C, transforming to a BCC (β phase) lattice above this temperature.(Alloying elements act to stabilize either of these phases meaning that the transformation temperature can be altered, and subsequently the proportions of each phase existing at room temperature can be varied. Titanium allows for the development of a range of bimodal→ microstructures which provide titanium alloys with inherent strength and also allows for further refinement of properties through various heat treatment and processing regimes. [2]

1.3Aluminium Alloy

Alloy A380 (ANSI/AA A380.0) is by far the most widely cast of the aluminium die-casting alloys, offering the best combination of material properties and ease of production. It may be specified for most product applications. Aluminium Alloys use in Electrical Conductors, Transport, Packaging, and High Pressure Gas Cylinders [2].

2. Literature Survey

Several literature is available on this era. Most of the authors have studied the blade profile and its design. Material properties have also studied which is used for GT blade. Few authors also focused on structural behaviour. Some of the conclusions were drawn on the basis of failure of blade profile. Most of the blades are failing on the top of the blade. High pressure and high temperature is the reason of failure. Outcomes of literature survey is as follows.

1) Higher pressure and temperature is the main reason of failure.
2) GT blade fails from top end.
3) GT blade fails before its designed life due to the hot sections.
4) Authors have focused on the design and blade profile.
5) GT blade metal also need more research.

3. CAD Model Preparation.

It is very critical to model the exact profile of GT blade as it is designed on micro level. Dimensions of blade profile are taken from the patent available [12]. CATIA V5R19 software is used to develop model. Figure 1 shows the CAD model of 1st stage GT blade.

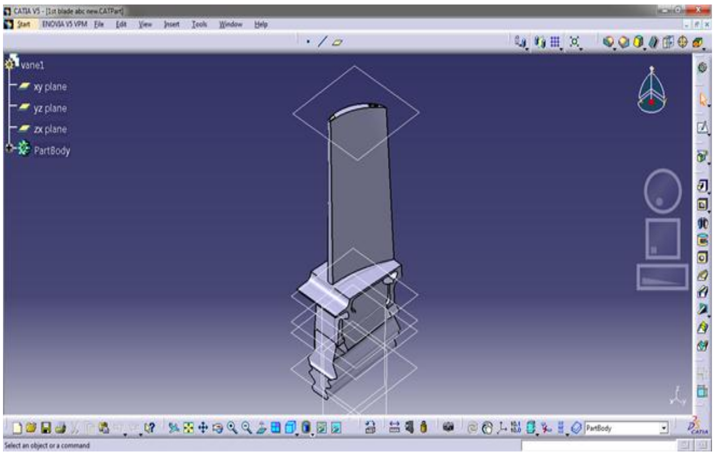

Fig. 1: CAD Model of 1st Stage GT Blade

Several commands are used to develop this CAD model in part module. The inner section of blade is having the cooling channels from which the cooled fluid (Air) flows which provide cooling effect to blade profile and hence the temperature of blade can be controlled. CAD model is further converted into .igs model to import it into a CAE software like ANSYS.

4. Thermal Analysis of GT Blade

Performance of thermal analysis on GT blade is one of the important step to find the hot spot on blade profile, heat affected zones and the thermal fluxes by which the performance of Blade material can be analysed well. As we know that the different metal will have different behaviour on high temperature. Hence according to their performance best metal can be suggested.

To perform thermal analysis we need to follow certain steps. Also we need some mechanical properties and boundary conditions. Mechanical properties of selected metals which we have chosen for analysis are as follows.

Table 1: Mechanical Properties of Gas Turbine Blade materials

Properties	**Units**	**Titanium Alloy**	**Stainless Steel Alloy**	**Aluminium 2024 Alloy**
Density (ρ)	Kg/ m^3	4700	8025	2725
Thermal Conductivity (K)	W/m -K	10	33.5	180
Coefficient of Thermal Expansion (α)	E-06/0 C	8.8	14.5	23.3
Specific Heat (C)p	J/Kg K	544	448	880
Modulus of Elasticity (E)	GPA	205	200	73
μ	---	0.33	0.3	0.33
Melting Point	0 C	1649	1451	565
Ultimate Tensile Strength	MPa	1000	1050	470

Thermal analysis is divided into three steps which are pre-processor, processor and post-processor. In pre-processor mechanical properties of metal, the meshing and boundary conditions (12000C Working Temperature) are assigned to imported CAD model. Meshing of CAD model is shown in figure 2.

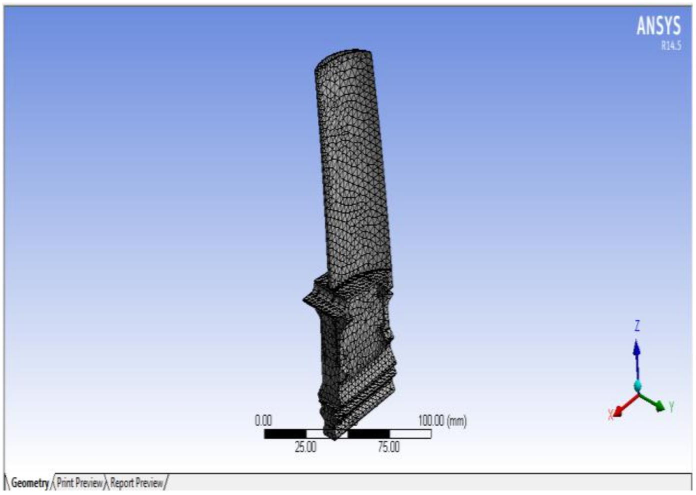

Fig. 2: Meshing of 1st Stage Gas Turbine Blade

Details of Gas Turbine blade meshing are as follows.

i) Maximum Nodes formed= 39687

ii) Maximum Elements created= 22355

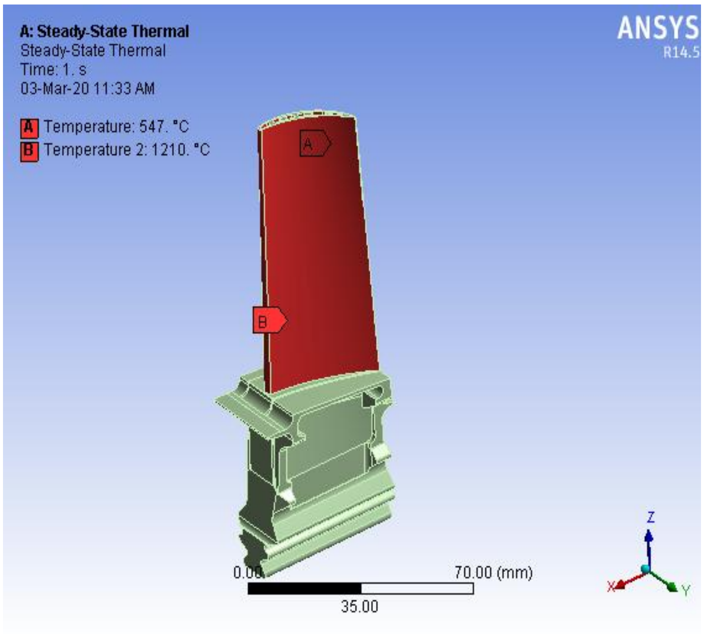

Fig. 3: Boundary Conditions Applied on GT Blade.

In second step which is known as processor step, software solved the FEM problem and generates result. Results are obtained in third step i.e. Post-processor step. Results obtained for titanium alloy blade are as follows.

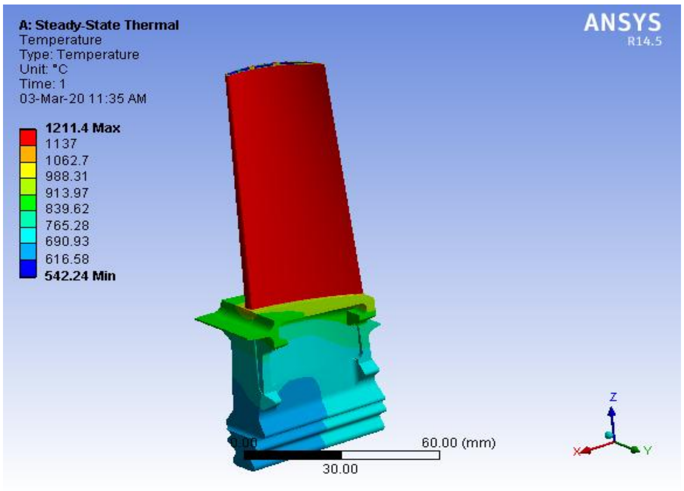

Fig. 4: Temperature Contours on Blade

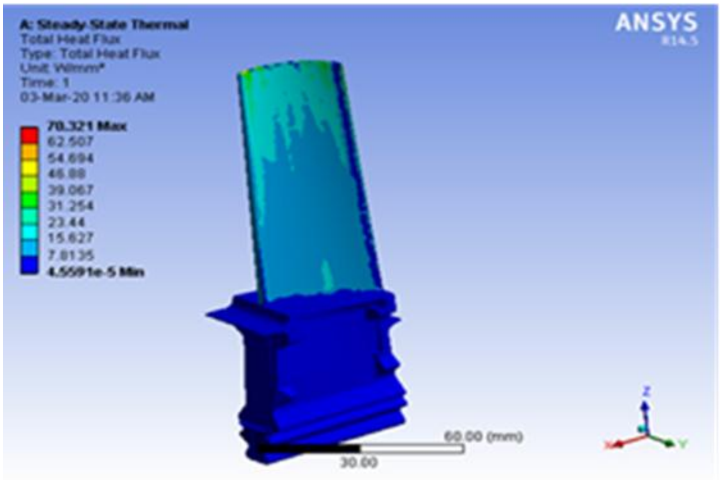

Fig. 5: Heat Flux contours on Blade

Figure 4 and Figure 5 shows the temperature contours and heat flux contours on GT blade. By observing carefully both results, it is clear that the entire blade profile is in the hot zone section. Inner section of GT blade having lower temperature compared outer profile. That is only because of cooling air flow inside the sections. Heat flux is the heat transfer rate per unit volume. Here the Heat transfer rate is 70.321 W/mm2. Maximum applied temperature is 1200 0C, but the temperature increases by 110C and it becomes 12110C.

Same thermal analysis is carried out by considering Stainless steel and aluminium alloy metals for GT blade. Their mechanical properties are applied while performing thermal analysis. Remaining procedure, model, mesh size and boundary conditions are same as before. Results obtained are summarised in following table.

Table 2: Results obtained for different analysis.

Sr.No.	Type of Alloy	Temperature Contour (0C)	Heat Flux Contour (W/mm2)
1	Titanium Alloy	1211.4	70.321
2	Stainless steel Alloy	1240.2	68.144
3	Aluminium Alloy	1251.2	67.224

5. Conclusion

By observing all results and table 2 we found titanium alloy results are better than the stainless steel and aluminium alloy results. The variation in the result is very less. All results are approximately same if we consider only heat flux. But temperature variation is more in all cases. Titanium alloy blade can give the better life as compared to other material.

REFERENCES

A.B. Moskalenkoa and A.I. Kozhevniko, "Estimation of Gas Turbine Blades Cooling Efficiency", ScienceDirect, International Conference on Industrial Engineering, ICIE 2016, Procedia Engineering 150 (2016) 61 – 67

Ahmed Abdulhussein Jabbar1, A. K. Rai2, P. Ravinder Reedy3 & Mahmood Hasan Dakhil4, "Design And Analysis Of Gas Turbine Rotor Blade Using Finite Element Method", International Journal of Mechanical and Production, Engineering Research and Development (IJMPERD), ISSN(P): 2249-6890; ISSN(E): 2249-8001, Vol. 4, Issue 1, Feb 2014, 73-94

Akhilesh Behera (111ME0282), " CFD Analysis of Matrix Cooling Method in Gas Turbine Blades", Department of Mechanical Engineering, NIT, Rourkela 769008

Je-Chin Han," Recent Studies in Turbine Blade Cooling", International Journal of Rotating Machinery, 10(6): 443–457, 2004, Copyright _c Taylor & Francis Inc.,

ISSN: 1023-621X print / 1542-3034 online, DOI: 10.1080/10236210490503978

Vijay K. Garg, AYT Research Corporation, Brook Park, Ohio "Heat Transfer in Gas Turbines", https://ntrs.nasa.gov/search.jsp?R=20010071841 2019-12-19T17:29:39+00:00Z

Jamison Janawitz, James Masso, Christopher Childs, "Heavy-Duty Gas Turbine Operating and Maintenance Considerations", GE Power & Water, Atlanta, GA

Schobeiri MT*, Department of Mechanical Engineering, Texas A&M University, College Station, Texas, USA, "Improving the Efficiency of Gas Turbines During Off-Design Operation by Adjusting the Turbine and Compressor Blade Stagger Angles", Journal of Applied

Mechanical Engineering, Schobeiri, J Appl Mech Eng 2018, 7:1, DOI: 10.4172/2168-9873.1000302

Pranay Pudake*, A. M. Elgandelwar and Mandar M.Lele, "Gas Turbine Blade Cooling Technology–A Case Study", International Journal of Current Engineering & Technology, E-ISSN 2277 – 4106, P-ISSN 2347 – 5161, ©2017 INPRESSCO®, All Rights Reserved Available at http://inpressco.com/category/ijcet

Theju V, Uday P S, PLV Gopinath Reddy, C.J.Manjunath, "Design and Analysis of Gas Turbine Blade", https://www.researchgate.net/publication/323902253, Uday Reddy on 21 March 2018.

Ahmed Abdulhussein Jabbar, A. K. Rai, P. Ravinder Reedy & Mahmood Hasan Dakhil, "Design And Analysis Of Gas Turbine Rotor Blade Using Finite Element Method", https://www.researchgate.net/publication/274373167, Ravinder Reddy Pinninti on 01 April 2015.

J.M. Gallardo, J.A. Rodr´ıguez, E.J. Herrera, " Failure of gas turbine blades", www.elsevier.com/lovcate/wear, Received 9 March,

Jianfu Hou, Bryon J. Wicks, Ross A. Antoniou," An investigation of fatigue failures of turbine blades in a gas turbine engine by mechanical analysis", Engineering Failure Analysis 9 (2002) 201–211, Received 28 November 2000; accepted 25 December 2000, 2002 Elsevier Science Ltd.

Z. Mazur a,*, A. Luna-Ramı´rez a, J.A. Jua´rez-Islas b, A. Campos-Amezcua, " Failure analysis of a gas turbine blade made of Inconelv 738 LC alloy", Engineering Failure Analysis 12 (2005) 474–486, www.elsevier.com/locate/engfailanal, Available online 23 November 2004

S. Barella, M. Boniardi, S. Cincera, P. Pellin, X. Degive, S. Gijbels, " Failure analysis of a third stage gas turbine blade", journal homepage: www.elsevier.com/locate/engfailanal, Engineering Failure Analysis 18 (2011) 386–393, doi:10.1016/j.engfailanal.2010.09.017

Liang Zheng, Chengbo Xiao, Guoqing Zhang, " Brittle fracture of gas turbine blade caused by the formation of primary β-NiAl phase in Ni-base superalloy", journal homepage: www.elsevier.com/locate/engfailanal, Engineering Failure Analysis 26 (2012) 318–324, http://dx.doi.org/10.1016/j.engfailanal.2012.07.014

BIOGRAPHIES

Rushikesh Misar

Prajwal Poharkar

Suraj Thakare