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Optimization and Thermal Analysis of Turbine Blade through Various Materials

Mukesh Kumar Prajapati
PG Scholar,
Pydah College of Engineering,
Kakinada, India.

J. Raja Sekhar
Associate Professor & HoD,
Pydah College of Engineering,
Kakinada, India.

Abstract

A turbine blade is the individual component which makes up the turbine section of a gas turbine. The blades are responsible for extracting energy from the high temperature, high pressure gas produced by the combustor. The turbine blades are often the limiting component of gas turbines. To survive in this difficult environment, turbine blades often use exotic materials like super-alloys and many different methods of cooling, such as internal air channels, boundary layer cooling, and thermal barrier coatings. Blade fatigue is a major source of failure in steam turbines and gas turbines. Fatigue is caused by the stress induced by vibration and resonance within the operating range of machinery. To protect blades from these high dynamic stresses, friction dampers are used.

In this project here we designed two different turbine blades and analysed with same boundary conditions with existing material steel and other two different materials also (Al-Alloy, U-500). Here we are calculating deformation, stress, safety factor results for all materials. To avoid resonance we also calculating their natural frequency values also. And also thermal loading conditions total temperature and total heat flux values. From all these here we can conclude which material is most suitable and which model will produce good efficiency.

Key Words: ***CATIA, NACA8610, NACA0012.***

1. INTRODUCTION

1.1 INTRODUCTION

A turbine blade is the individual component which makes up the turbine section of a gas turbine. The blades are responsible for extracting energy from the high temperature, high pressure gas produced by the combustor. The turbine blades are often the limiting component of gas turbines. To survive in this difficult environment, turbine blades often use exotic materials like super-alloys and many different methods of cooling, such as internal air channels, boundary layer cooling, and thermal barrier coatings. Blade fatigue is a major source of failure in steam turbines and gas turbines. Fatigue is caused by the stress induced by vibration and resonance within the operating range of machinery. To protect blades from these high dynamic stresses, friction dampers are used.

2. DESCRIPTION

2.1 CAD DESIGN TOOL (CATIA)

CATIA is a suite of programs that are used in the design, analysis, and manufacturing of a virtually unlimited range of product. CATIA is a parametric, feature-based solid modeling system, “Feature based” means that you can create part and assembly by defining feature like pad, rib, slots, holes, rounds, and so on, instead of specifying low-level geometry like lines, arcs, and circle& features are specifying by setting values and attributes of element such as reference planes or surfaces direction of creation, pattern parameters, shape, dimensions and others.

Catia design procedure

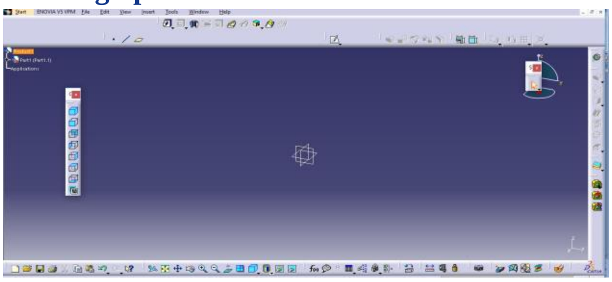

Fig: Catia tool interface

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The above image shows the catia tool interface hare we have 3 planes which are xy, yz ,zx and according to our requirement we select one plane and draw the sketch.

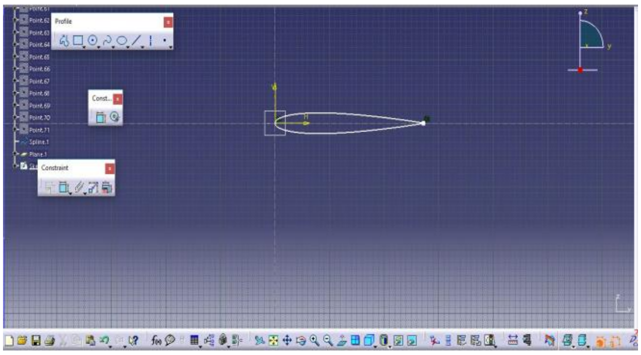

Fig: Aerofoil shape in Catia

After importing the sketcher and increase its scale range upto 27cm and make sure that the sketcher should be closed and there should be no open ends and there should be no over lapping also.

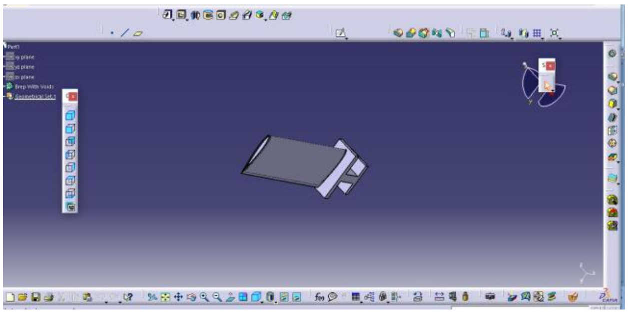

Fig: naca 8610 aerofoil

2.2 ANSYS ANALYTICAL SYSTEM

For all engineers and students coming to finite element analysis or to ansys software for the first time, this powerful hands-on guide develops a detailed and confident understanding of using ansys's powerful engineering analysis tools. the best way to learn complex systems is by means of hands-on experience.

2.2.1 STRUCTURAL ANALYSIS

Table 1: Engineering data of different materials

STEEL	Al-7075 T6	U-500
Density (kg/m^3): **7850**	Density (kg/m^3): **2823.3**	Density (kg/m^3): **8550**
Young's modulus (Pa): **2e11**	Young's modulus (Pa): **7.1e10**	Young's modulus (Pa): **1.9e11**
Poisons ratio: **0.3**	Poisons ratio: **0.33**	Poisons ratio: **0.3**
Yield strength (Mpa): **250**	Yield strength (Mpa): **580**	Yield strength (Mpa): **275**

After importing model just click on geometry option then we will get selection of material from engineering data here we already applied steel and u-500 and al-7075 material properties.

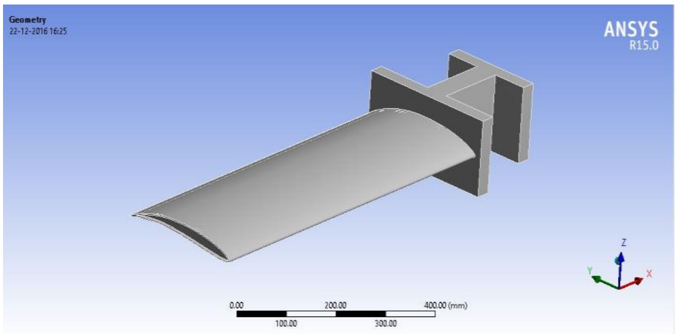

Fig: Model imported from pro-e tool in iges format.

After completion of material selection here we have to create meshing for each object meshing means it is converting single part into no of parts. And this mesh will transfer applied loads for overall object. After completion meshing only we can solve our object. Without mesh we cannot solve our problem. And here we are using tetra meshing and the model shown in below.

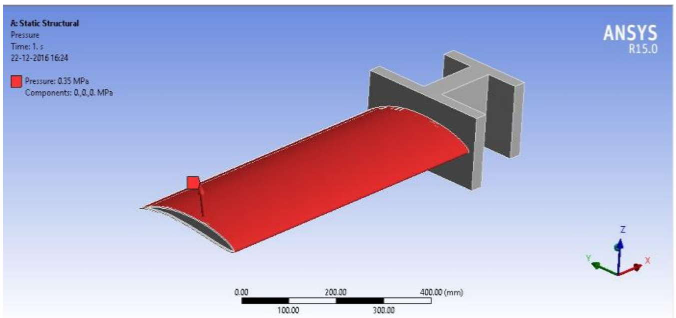

Fig: boundary conditions of the turbine blade and here we applied 0.15Mpa

2.2.2 THERMAL ANALYSIS

Table: Steady state thermal values of different materials

Al-alloy thermal conductivity:	130 w/m/c
Steel thermal conductivity:	60.5 w/m/c
u-500 thermal conductivity:	16.2 w/m/c
bulk temperature	850*c
Film coefficient	1.24e-6w/mm^2
Film coefficient	0.12457 w/mm^2

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Steel:

Total temperature

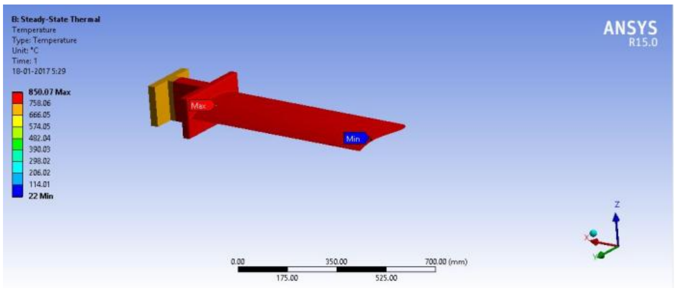

Fig: total temperature of Steel

Total heat flux

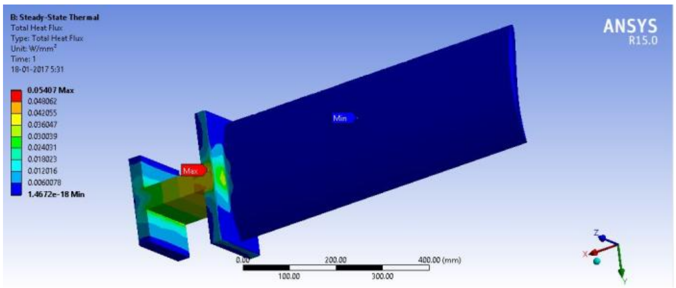

Fig: total flux heat of Steel

U-500

Total temperature

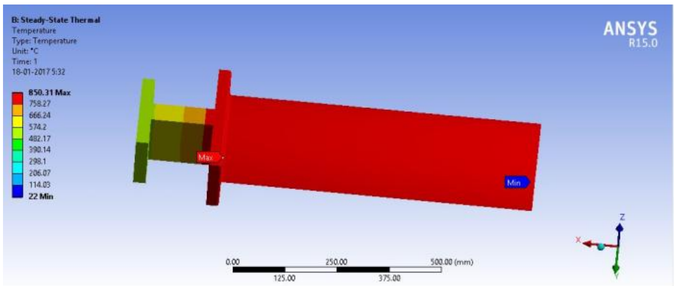

Fig: total temperature of U-500

Total heat flux

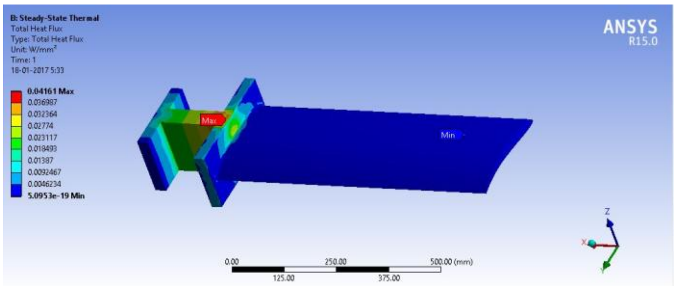

Fig: total flux heat of U-500

Al-Alloy

Total temperature

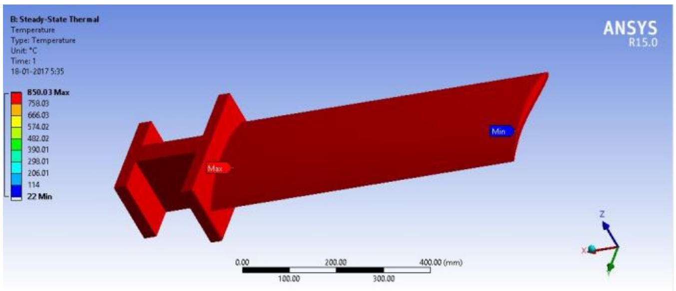

Fig: total temperature of Al-alloy

Total heat flux

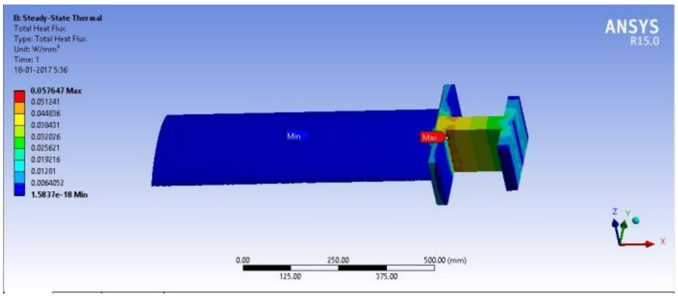

Fig: total flux heat of Al-Alloy

2.2.3 MODEL ANALYSIS

Mode1

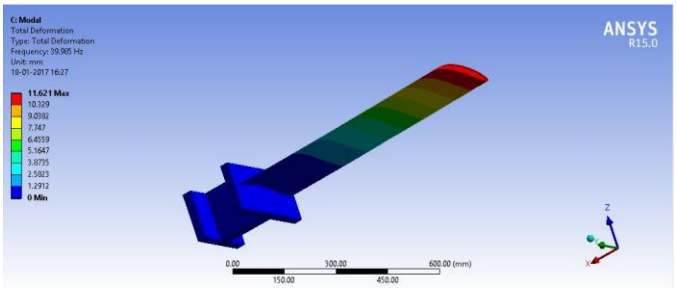

Fig: mode1 of 8610

Mode5

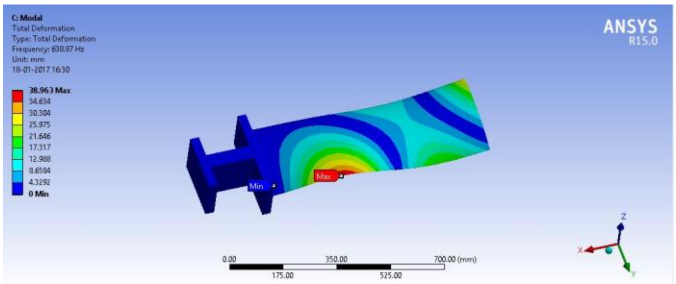

Fig: mode5 of 8610

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Table: natural frequencies of different materials

Naca 8610	STEEL	U-500	AL-7075
Mode1 (Hz)	39.985	37.343	39.839
Mode2 (Hz)	218.63	204.19	215.13
Mode3 (Hz)	243.58	227.49	242.46
Mode4 (Hz)	304.26	284.16	302.49
Mode5 (Hz)	645.01	602.39	638.87
Mode6 (Hz)	683.23	640.25	666.98
Mode7 (Hz)	772.4	721.37	784.93
Mode8 (Hz)	876.78	818.85	879.44
Mode9 (Hz)	930.44	868.96	938.19
Mode10 (Hz)	1076.5	1005.4	1085.8
Mode11 (Hz)	1222.7	1141.9	1228.5
Mode12 (Hz)	1341.9	1253.3	1356.9
Mode13 (Hz)	1513.9	1413.9	1521.5
Mode14 (Hz)	1542	1440.1	1537
Mode15 (Hz)	1588	1483.1	1599
Mode16 (Hz)	1656.6	1547.1	1648.5
Mode17 (Hz)	1673.5	1563	1684.1
Mode18 (Hz)	1904.5	1778.7	1926.9
Mode19 (Hz)	1955.9	1826.7	1973.9
Mode20 (Hz)	2034.8	1900.4	2053.3

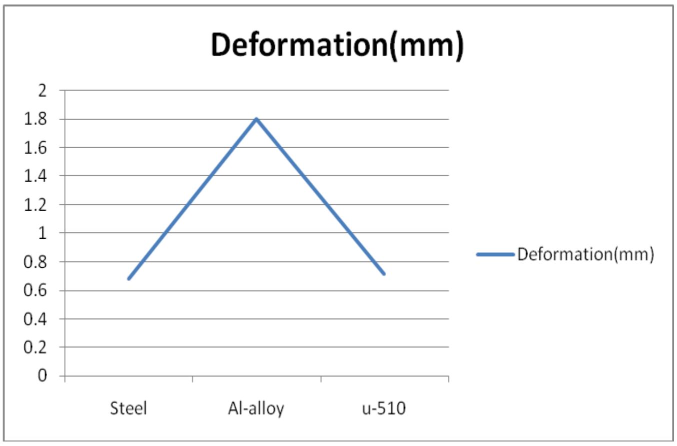
3. RESULT

By using cad tool (catia) design foil software here we took naca8610, naca0012 turbine blades we developed complete models and obtained following results.

Table: Parameters of different materials

	Deformation(mm)	Stress(mpa)	strain	Safety factor
Steel	0.67938	204.47	0.0012087	1.2227
Al-alloy	1.8	196.99	0.0033242	2.9443
u-500	0.71514	204.47	0.0012723	1.345

Deformation



Deformation

Stress

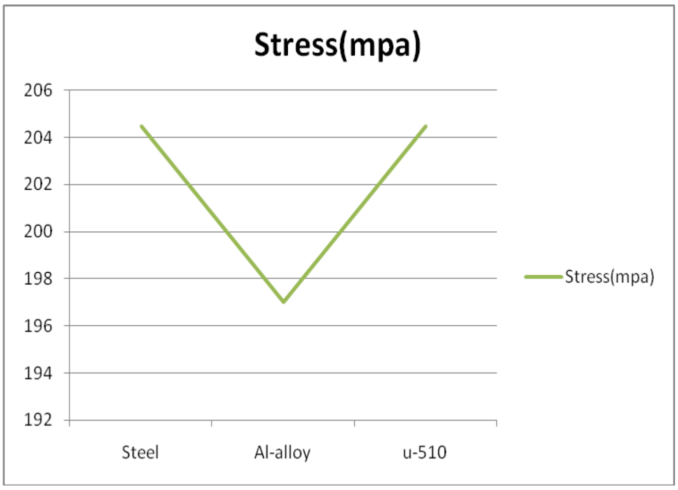


Fig: Stress

Strain

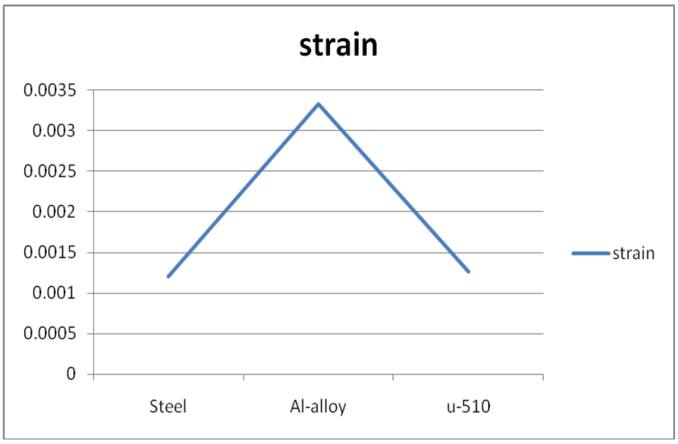


Fig: Strain

Safety factor

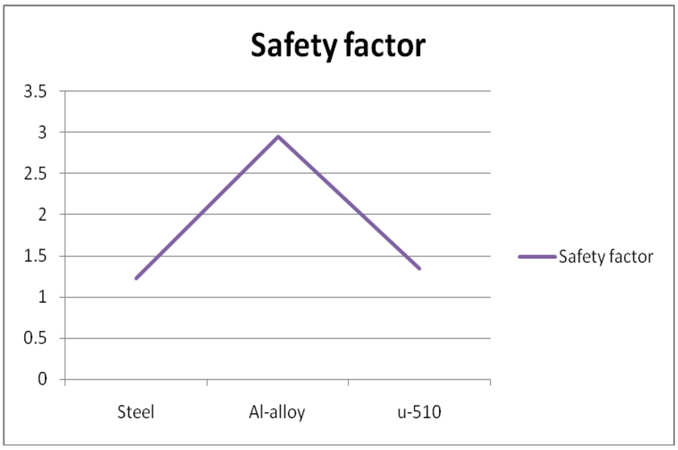


Fig: Safety factor

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Table: Parameters of different materials

NACA 8610	STEEL	U-500	AL-7075
Total temperature (°c)	850.07	850.31	850.03
Total heat flux (w/mm^2)	0.05407	0.04161	0.057647
Heat flux in x	0.04885	0.037826	0.051988
Heat flux in y	0.028259	0.021231	0.030346
Heat flux in z	0.019764	0.016651	0.021324

4. CONCLUSION

In this project we designed two different turbine blades by using cad tool (CATIA). By using design foil software here we took NACA8610, NACA0012 turbine blades key points and directly imported into CATIA. By using these key points we developed complete models. And 8610 turbine blade is an existing model and it has steel material. To improve its efficiency here we also chosen 2 different materials those are (al-alloy, u-500). To calculate its static and thermal loading results we imported into CAE tool (Ansys workbench) analysed with their respective boundary conditions. When we using NACA8610 turbine blade al-alloy decreasing stress compare to existing material steel. In NACA 0012 turbine the stresses are high compare to existing model but the al-alloy is maintaining good safety factor values than existing model(NACA8610(steel)).

In thermal loading conditions the both models total temperature is approximately equal and the heat flux value is high for NACA 0012 model it means it has high heat transfer rate than naca8610.And the turbine blade mostly a vibrating model, to avoid resonance of the object we also calculated natural frequency of the models. In these modes naca0012 has higher frequency range than naca8610 it means naca0012 has higher strength than existing model.From all static thermal and dynamic loading conditions results, here we came to know that we can use naca0012 al-alloy model with the replacement of naca8610 turbine (steel) blade.

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