Modeling and Analysis of Steam Turbine Blade by Varying Its Profile

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Abstract— A steam turbine is mechanical device which converts thermal energy in steam into mechanical work. The steam turbine gives the better thermodynamic efficiency by using multiple stages in the expansion of steam. The stages are characterized by the way of energy extraction from them is considered as impulse or reaction turbines. In this thesis the parameters of steam turbine blade varied and analysis is done for strength, life and heat transfer rates. The varied parameters are the ratio of X-axis distance of blade profile by chord length and ratio of maximum height of blade profile in Y-direction to the chord length. The 2D modelling is done by using pro/engineer. The ANSYS software is used for static, thermal and fatigue analysis.

Key words: Steam Turbine, Thermal Energy, Impulse Turbine, Reaction Turbine, Static Analysis, Fatigue Analysis, Thermal Analysis

I. INTRODUCTION

A. *Steam Turbine:*

A turbine is a mechanical device that extracts energy from fluid flow and converts into mechanical work. Turbine is a turbo machine with minimum one moving part known as rotor assembly which is shaft with blades attached. The moving fluid that is made to flow through blades creates movement in blades by which they impart rotational energy to the rotor.

Steam, water and Gas turbines have casing around the moving blades to control the working fluid. Due to the rotary motion generated by turbine , it is particularly used to drive an electrical generator (nearly more than 90% of all electricity generation in united states is by using of steam turbines) , the view of steam turbine blade is shown below.

Fig. 1: Turbine

B. *Types of Turbines:*

- Steam turbine
- Gas turbine
- Transonic turbine
- Contra-rotating turbine
- Statorless turbine
- Ceramic turbine
- Shroudless turbine
- Bladeless turbine
- Water turbines
- Wind turbines
- Velocity compound
- Pressure compound multi stage impulse
- Mercury vapour turbines

C. *Operation Theory:*

Impulse turbines can change the direction of flow of high velocity fluid or gas. The resulting impulse spins the turbine and allows the fluid to flow with diminished kinetic energy. The pressure of the fluid or gas in the turbine blades does not varies. Pelton wheels and De Laval turbines will follow this process.

Reaction turbines creates torque by reacting to the fluid or gas pressure or mass. In this case the pressure changes when it passes through the blades. Newton's 3rd law explains the transfer of energy in this turbines.

Now a days modern turbines use both impulse and reaction concepts based on requirement. The operation of impulse and reaction are shown below.

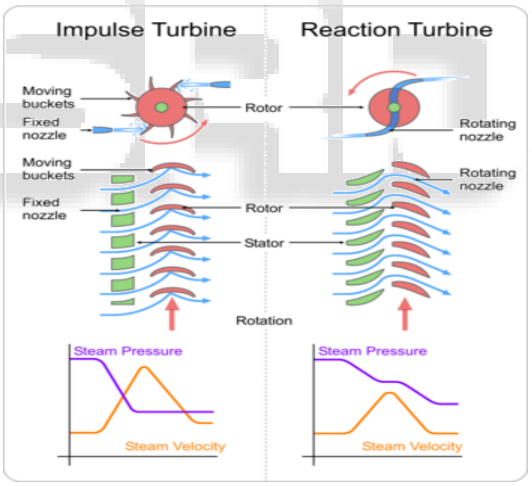

Fig. 2: Impulse And Reaction Turbine Operation

II. MATERIAL AND METHODS

The material used for the turbine blade is chromium steel. The material properties of chromium steel is tabulated below

Specification	Amount
Young's modulus	200GPa
Density	7.70 g/cc
Poisson ratio	0.32

Table 1: Properties of Chromium Steel

Models	X/c	Yh/c	Yd/c
Case1	25.69	16.88	1.42
Case 2	30.10	18	2
Case 3	35	20	3

Table 2: Specifications of The Blade

Where

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X/c= ratio of X axis distance of blade profile by chord length
Yh/c= ratio of maximum height of blade profile in Y direction to the chord length
Yd/c= ratio of minimum height of blade profile in Y direction to the chord length

A. Models of Turbine Blades:

CASE 1:

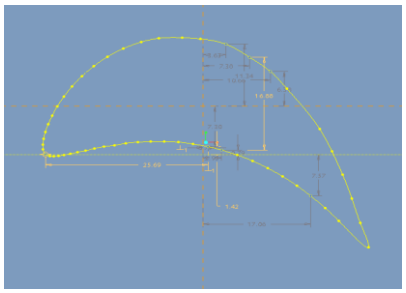

Fig. 3: Sketcher Profile of Blade

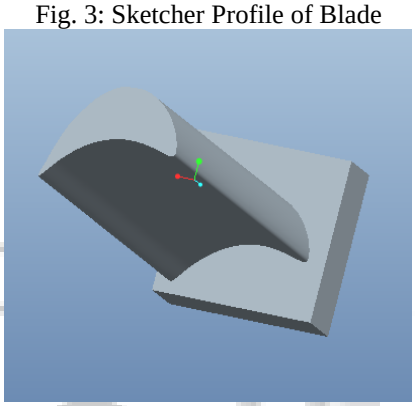

Fig. 4: Blade with Base

CASE 2

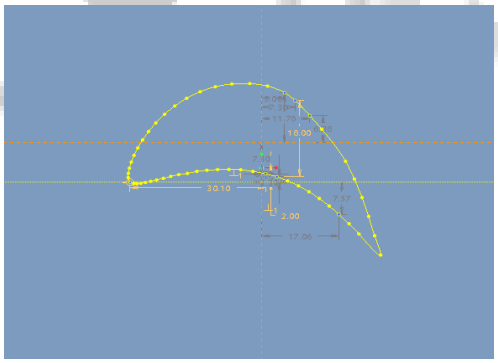

Fig. 5: Sketcher Profile of Blade

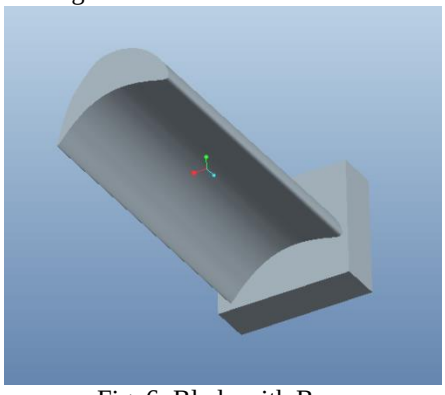

Fig. 6: Blade with Base

CASE 3:

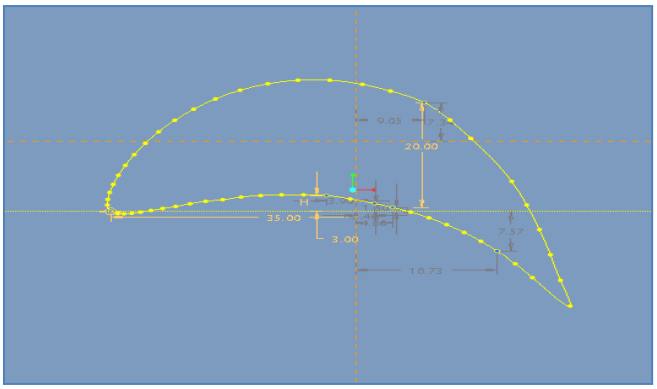

Fig. 7: Sketcher Profile of Blade

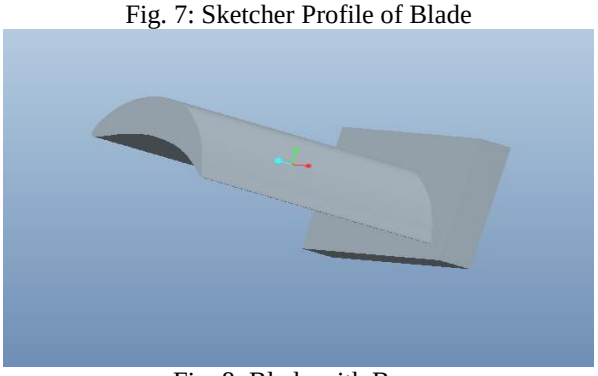

Fig. 8: Blade with Base

B. Load Calculations:

F = M*Vm
M = mass of steam flowing through turbine
Vm= velocity of steam in m/s
M= 1000kg/hr
Vm= 1310 m/s
F= 362.87N
Blade area= 23319.1mm²
Pressure = F/A
P= 0.01556N/mm²

III. RESULTS AND DISCUSSIONS

After carrying out the analysis the obtained results are acquired as follows

A. Structural Analysis:

1) CASE 1:

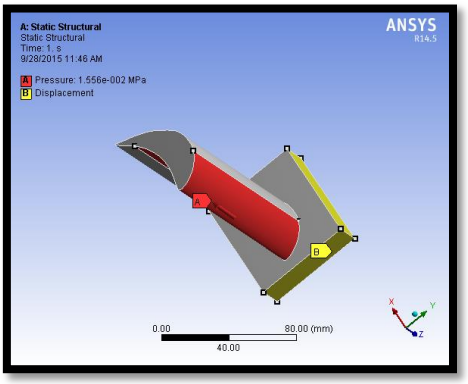

Fig. 9: Boundary Conditions Applied To Blade

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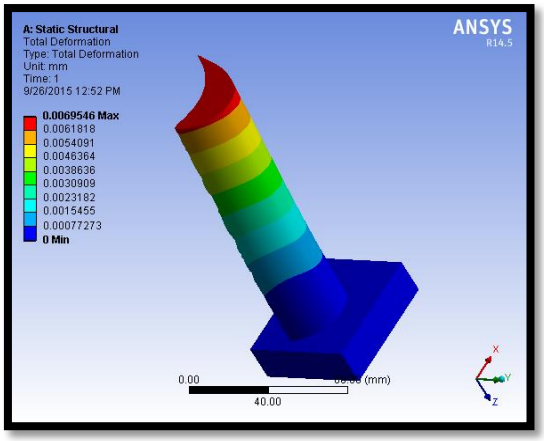

Fig. 10: Deformation of Blade

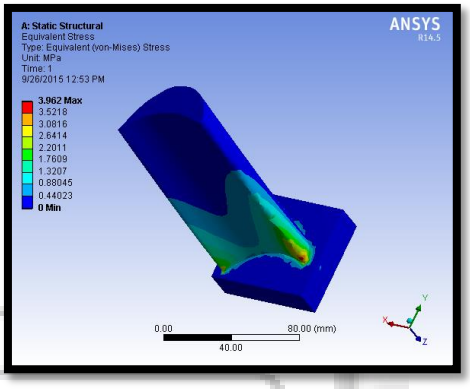

Fig. 11: Stress Occurred In Blade

2) Case 2:

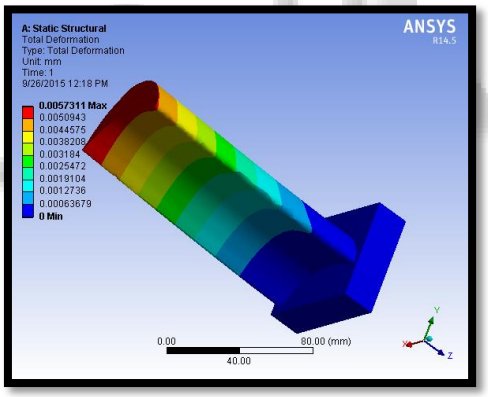

Fig. 12: Deformation of Blade

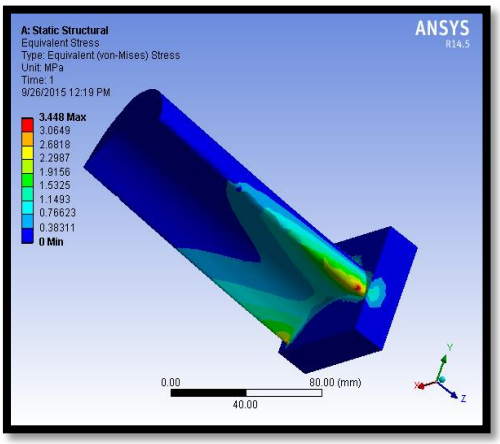

Fig. 13: Stress Occurred In Blade

B. Case 3:

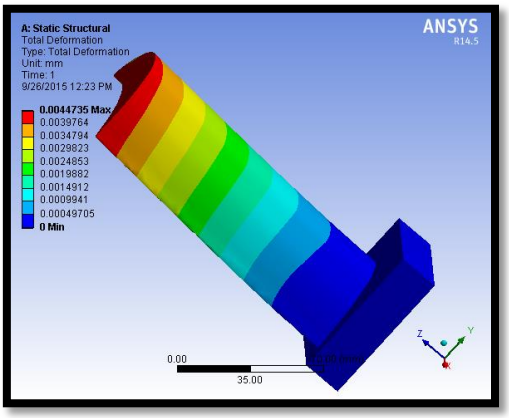

Fig. 14: Deformation of Blade

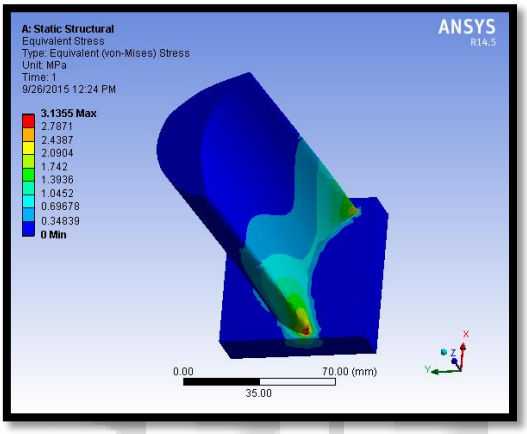

Fig. 15: Stress Occurred In Blade

C. Thermal Analysis:

1) Case 1:

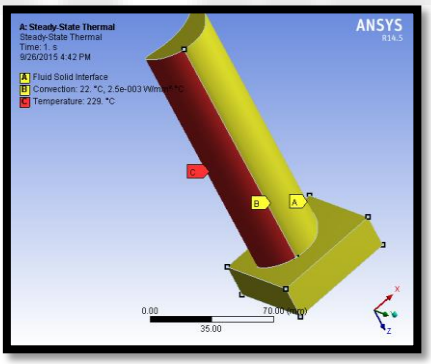

Fig. 16: Boundary Conditions Applied To Blade

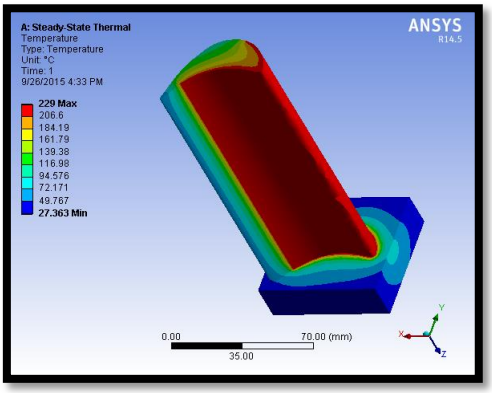

Fig. 17: Nodal Temperature Of A Blade

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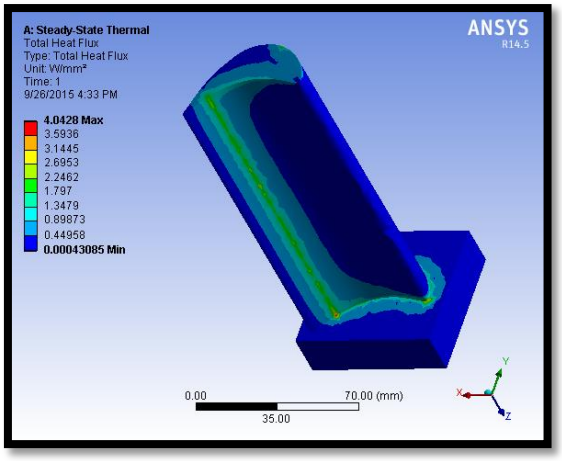

Fig. 18: Heat Flux Of Blade

D. Fatigue Analysis:

1) Case 1:

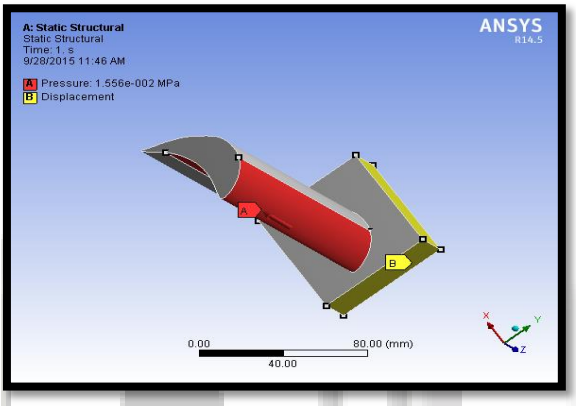

Fig. 19: Boundary Conditions of Blade

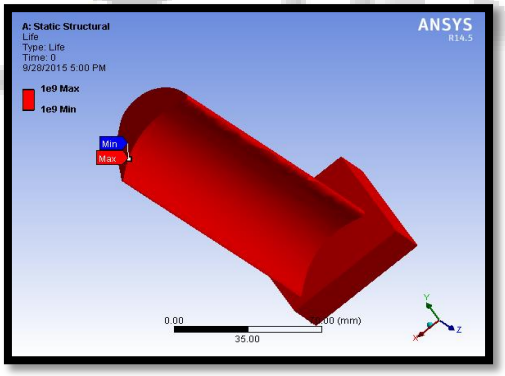

Fig. 20: Life of the Blade

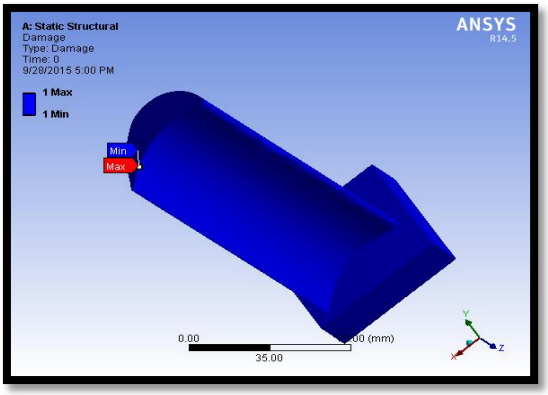

Fig 21: Damage of Blade

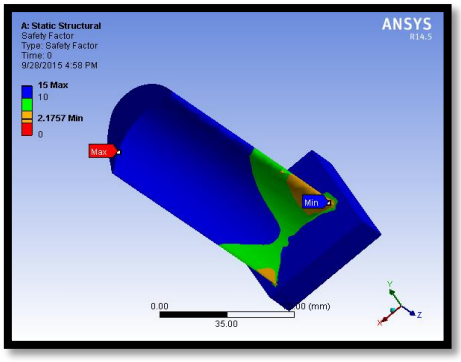

Fig. 22: Safety of Factor of the Blade

The results obtained from the analysis are tabulated below

Models	Deformation(mm)	Stress (MPa)
Case 1	0.0069546	3.962
Case 2	0.0057311	3.448
Case 3	0.0044735	3.1355

Table 3: Structural Analysis Results

Models	Temperature (˚C)	Heat flux(w/mm²)
Case 1	229	4.0428
Case 2	229	2.1728
Case 3	229	1.8392

Table 4: Thermal Analysis Results

Models	Life	Damage	Safety of factor (minimum)	Safety of factor (maximum)
Case1	1e9	1	2.1757	15
Case 2	1e9	1	2.5	15
Case 3	1e9	1	2.7491	15

Table 5: Fatigue Analysis Results

The results obtained from the static, thermal and fatigue analysis shows that the stress values are decreasing 13% from case1 to case 2 and 21% from case 1 to case 3 by increasing parameters, transfer rate reduced by 46%from case 1 to case 2 and 54.5% from case 1 to case 3 by increasing parameters. The safety of factor is also increased by increasing of parameters.so by increasing parameters would give better results.

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