Modeling and Analysis of Micro Gas Turbine Compressor Different Parts

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Abstract

The work displayed in the report is an endeavor at planning a miniaturized scale turbine of a given measurement. Broad writing audit was done to contemplate the different perspectives and utilizations of small scale turbines. An appropriate outline methodology was looked over the accessible strategies to plan distinctive parts of miniaturized scale turbine. CATIA is utilized broadly to make parts with diff sorts of tasks. At that point every one of the parts are collected for making a total turbine in CATIA Get together area. At that point they are sending for fast prototyping.

Keyword: Modeling, Micro Gas Turbine, Compressor Different Parts

1. Introduction

Miniaturized scale turbines are little ignition turbines which are having yield extending from 20 kW to 500 kW. The Advancement is from car and truck turbo chargers, assistant power units (APUs) for planes, and little stream motors. Miniaturized scale turbines are generally new dispersed age innovation which is utilized for stationary vitality age applications. Regularly they are burning turbine that produces both warmth and power on a moderately little scale.

2. Literature review

A turbine can be utilized as a refrigerant machine was first presented by Ruler Rayleigh. In a letter June 1898 to Nature, he proposed the utilization of turbine rather than a cylinder expander for air liquefaction in light of pragmatic challenges caused in the low temperature responding machines. He underlined the most imperative capacity of and cryogenic expander, or, in other words of the cool, as opposed to the power delivered.

In 1898 The English specialist Edgar C Thrupp licensed a basic melting framework utilizing an extension turbine. Thrupp's expander was a twofold stream machine entering the middle and isolating into two oppositely streaming streams.

A regenerative extension turbine with an unrelated internal stream design was protected by the Americans Charles F and Orrin J Crommett in 1914. Gas was to be admitted to the turbine wheel by a couple of spouts, yet it was indicated that any coveted quantities of spout could be utilized. The turbine cutting edges were bended to introduce marginally curved countenances to the fly from the spout. These cutting edges were relatively short, not surpassing near the rotor center point.

In 1922, the American specialist and educator Harvey N Davis had protected an extension turbine of abnormal thermodynamic idea. This turbine was planned to have a few spout hinders each accepting a flood of gas from various temperature level of high weight side of the principle warm exchanger of a liquefaction mechanical assembly.

First fruitful business turbine created in Germany which utilize a hub stream single stage motivation machine. Later in the year 1936 it was supplanted by an internal outspread stream turbine dependent on a patent by an Italian creator, Guido Zerkowitz.

Work on the little gas bearing turbo expander initiated in the mid fifties by Sixsmith at Perusing College on a machine for a little air liquefaction plant. In 1958, the Unified Kingdom Nuclear Vitality Specialist built up a spiral internal stream turbine for a nitrogen generation plant. Amid 1958 to 1961 Stratos Division of Fairchild Air ship Co. fabricated blower stacked turbo expanders, for the most part for air division benefit. Vothet. Built up a rapid turbine expander as a piece of a chilly mediator cooler for the Argonne National Lab (ANL). The main business turbine utilizing helium was worked in 1964 of every a fridge that created 73W at 3K for the Rutherford helium bubble chamber. A fast turbo alternator was produced by General Electric Organization, New York in 1968; this kept running on a commonsense gas bearing framework fit for working at cryogenic temperature with low misfortune.

Yang et al., built up a two phase scaled down development turbine made for a 1.5 liters/hour helium liquefier at the Cryogenic Building Lab of the Chinese Institute of Sciences. The turbines pivoted at in excess of 500,000 rpm. The plan of a little, rapid turbo expander was taken up by the National Department of Models (NBS) USA. The main expander worked at 600,000 rpm in remotely pressurized gas course. The turbo expander created by Kate et al., was with variable stream limit instrument (a movable

turbine), which had the limit of controlling the refrigerating force by utilizing the variable spout vane tallness.

India has been lingering behind whatever is left of the world in this field of innovative work. In any case, critical advancement has been made amid the previous two decades. In CMERI Durgapur, Jadeja built up an internal stream outspread turbine bolstered on gas course for cryogenic plants. The gadget gave stable revolution at around 40,000rpm. The program was, be that as it may, stopped before any noteworthy advancement could be accomplished. Another program at IIT Kharagpur built up a turbo expander unit by utilizing aerostatic push and diary heading which had a working rate up to 80,000 rpm. As of late Cryogenic Innovation Division, BARC created Helium cooler equipped for delivering 1 kW at 20 K temperature.

Improvement of a stage fit for recreating the execution of gas turbines connected in street vehicles. The creator's effort centered around the advancement of two devices: an executable code equipped for making the efficiency guide of any gas turbine display, in view of information produced by business programming (GasTurb) that assesses the motor thermodynamic cycle for both outline and of-plan operational conditions.

The utilization of small scale turbine generators in cross breed electrical vehicles - Power prepares The record quickly depict a few thoughts for ultra-low discharge utilizing smaller scale turbine In an arrangement half breed configuration(HIL Tech improvement constrained)

Millimeter-Scale, MEMS Gas Turbine Motors Enhanced convenient gadgets with the quickly extending ability of micromachining innovation has made possible minimal power hotspots for the improvement of gas turbines in the millimeter-measure run. With airfoil traverses estimated in 100's of microns instead of meters, these "miniaturized scale motors" have around 1 millionth the wind current of vast gas turbines and accordingly should deliver around 1 millionth the power, 10– 100W.

MEMS-Idea Utilizing Small scale Turbines for Satellite Power Supply These Power-MEMS will be utilized as an option in contrast to batteries for workstations, camcorders or other power devouring versatile applications. The examination gathering of Reynaerts (Branch of Mechanical Designing, College of Leuven, Belgium) (Peirs et al., 2003) has built up a Power-MEMS utilizing a solitary stage pivotal smaller scale turbine with a rotor distance across of 10 mm This turbine is an initial phase in the advancement of a miniaturized scale generator.

Improvement of a Synergist Smaller scale combustor For Hydrocarbon-filled Power MEMS This paper reports the advancement of a high proficiency, hydrocarbon-energized miniaturized scale burning framework for a small scale gas turbine motor for power age and miniaturized scale drive applications. A three-wafer synergist combustor was manufactured and tried. Efficiencies more than 40% were accomplished for ethylene-air and propane-air ignition.

Configuration Concentrate for Single Stage High Weight Turbine of Gas Turbine Motors, Ajoko, Tolumoye John - The exploration paper is an outline concentrate to diminish different phases of High Weight Turbine (HPT) to keep up a similar push – to – weight proportion of gas turbines. This current methodology of gas turbine configuration is to lessen cost and weight of the part.

Miniaturized scale gas turbine arrangements with carbon catch e Execution appraisal utilizing an approved thermodynamic model Mohammad Mansouri et al., is exhibited. CO2 catch unit is coordinated to the benchmark MGT display. Small scale gas turbine utilizing EGR and Cap cycles with CO2 catch is additionally explored. Impacts of surrounding temperature minor departure from the cycles' execution are displayed. A significant change in cycle productivity for the Cap cycle is appeared.

Life investigation of modern gas turbines utilized as a back-up to inexhaustible the assessed life of gas turbines is relied upon to lessen after some time when contrasted with the makers' evaluated life, especially when utilized as a back-up to Sustainable power Sources (RES). As RES are been brought into the lattice, the gas turbines utilized related to them are worked in "Load-Following" modes to these RES which incorporates wind, warm, sun powered, and so forth.

Small scale gas turbine based test fix for cross breed framework copying - the thermo concoction control gathering (TPG) is working at the research center of the college of genoa, italy, another high temperature energy unit - miniaturized scale gas turbine physical emulator dependent on business machine innovation.

Accomplishing hub equalization of a small scale turbine rotor with low bearing weights for start-up and fast task - adaptation of the weight field around a 4mm distance across rotor of a smaller scale turbine was done to see the cooperation between the segments (multistage miniaturized scale turbine, winding furrow gooey seals and pump, hydrostatic direction) and their effect on pivotal power and solidness to accomplish low push bearing hub balance.

3. Development of model

3.1. General procedure adopted for modeling the micro turbine

PRO/E Part Application
1. Datum planes
2. Pad, Pocket - Extrude
3. Edge Fillet
4. Holes

Table 1: Compressor Geometry Parameter		
Items	**Parameter**	**Value**
Shaft Diameter	D(mm)	20
Impeller Inner Diameter	D_1(mm)	55
Impeller Outer Diameter	D_2(mm)	136
Impeller Thickness to Shaft	h(mm)	42
Impeller Outflow Thickness	b(mm)	4.825
Blade Degree	β(degree)	23.20
Blade Number	-	16

3.2. Build geometry in CATIA

Step 1: 2d Sketch has been Drawn Using Component Drawing.
i.   Start > mechanical design >sketcher.
ii.   In the sketcher work bench 2d drawing has been drawn using different sketch. Tools like line, circle, spline, arc, fillet etc, as per component drawing.

Step 2: Shaft Option is Used to Revolve the 2D Sketch in to Part Design of Disc.
i.   After exiting sketcher workbench select the part design.
ii.   Select the shaft option.
iii.   Revolve the 2d sketch with respect to x axis.

Step 3: 2d sketch's of blade has been imported and joined by combine solid option.
i.   X,yand z co ordinates of an aero foil has been taken in notepad and imported to CATIA.
ii.   Similarly seven aerofoil's has been imported.
iii.   Using solid combine option all the seven aerofoil's are combined to form a blade.

Step 4: Circular pattern option is used to make one blade to 42 blades.

Step 5: Fillet radius between the blade and the disc is increased from 4.5
i.   in the part design workbench fillet option is selected

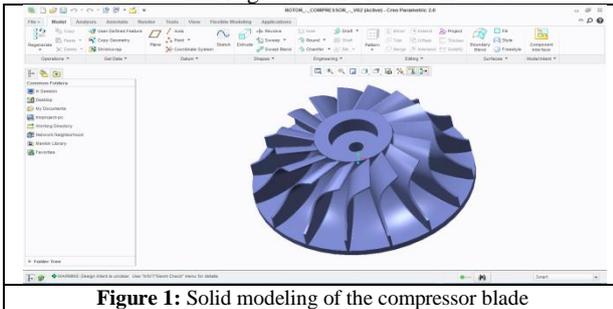ii.   radius 4.5mm is given at the root of the blade

Figure 1: Solid modeling of the compressor blade

4. Finite element analysis

It is not possible to obtain analytical solution for many engineering problems. At the engineering solution is a mathematical model or expression that gives the value of the field variable at any location in the body.

4.1.Mathematical background

ANSYS creates differential equations on each element. These equations are called as elementary equations. In ANSYS the law of conservation of mass was used for pressure and momentum principle for velocity and energy principles for temperature.

4.2.ANSYS

Generally extremely confused models are demonstrated in Master/E V5 and after that foreign made in ANSYS programming. IGES choice is utilized for this reason. IGES implies Introductory Illustrations Trade Particular. This is a standard configuration for exchanging computer aided design documents from one to the next. The 4 stroke cylinder displayed in Star/E V5 is transported in to ANSYS utilizing this alternative.

4.3.Methodology utilized in ANSYS

The ANSYS program has numerous limited component investigation abilities, going from a basic, straight, static examination to an intricate, nonlinear, transient powerful investigation. The examination control manuals in the ANSYS documentation set portray particular strategies for performing investigations for various building disciplines. The following couple of areas of this part cover general advances that are regular to generally examinations

4.4.A typical ANSYS analysis has three distinct steps

Step 1: Mesh the Volume

i.   Main Menu>Preprocessor>Meshing>Mesh Tool
ii.   Choose Manual Size Controls, you simply specify a mesh size level from 1 (fine mesh) to 10 (coarse mesh). Select free mesh and press OK
Step 2: Apply Inertial Load
MainMenu>Preprocessor>Loads>DefineLoads>Apply>Structural>Inertia>Angul-ar Velocity>Global>Omega>Enter the value on the correct axis(X, Y, Z).
Step 3: Apply Boundary Condition
Main   Menu>Solution>DefineLoads>Apply>Structural>Displacement> On Areas> Select the Areas.
Main   Menu>Solution>Define   Loads>Apply>Structural>Displacement>Symmetry B.C> On Areas> Select the symmetrical areas.

Step 4: Thermal Analysis
Obtain Solution
Step 5: Solve Main Menu > Solution > Solve > Current LS
i.   Review the information in the Status Window, then choose File> Close (Windows) or Close(X11/motif), to close the window.
ii.   OK to begin the solution.
iii.   Choose yes to any Verify message that appears.
iv.   Close the information window when the solution is done.
Review Results
Step 6: Plot the Deformed Shape
   i.   Main menu > General Postproc > Plot Result > Deformed Shape
   ii.   Choose Def + Unreformed
   iii.   OK
   iv.   You can also produce an animated version of the deformed shape.
   v.   Utility Menu > Plot Controls > Animate > Deformed Shape
   vi.   Choose Def + Unreformed
   vii.   OK
Step 7: Plot the von Misses equivalent stress
   i.   Main Menu > General Post process > Plot Result > Contour Plot > Nodal Solution.
   ii.   Choose Stress item to be contoured.
   iii.   Scroll down and choose von Misses (SEQV).
   iv.   OK
   v.   You can also produce an animated version of these results.
   a.   Utility Menu > Plot Controls > Animate > Deformed Results.
   vi.   Choose Stress item to be contoured.
   vii.   Scroll down and choose von Misses (SEQV).
   viii.   OK.
Step 8: Exit the ANSYS Program
   i.   When leaving the ANSYS program, you can spare the geometry and load parts of the database (Default), spare geometry, burdens and arrangement information, and post preparing information (i.e. spare everything), or spare nothing. You can spare nothing here except for you ought to make sure to utilize one of the other spare alternatives in the event that you need to keep the ANSYS information documents. Tool bar : Quit
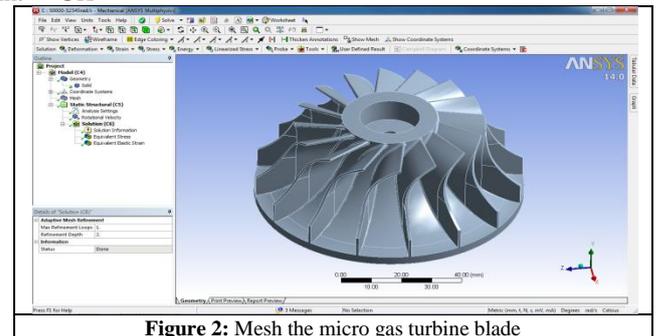ii.   Choose Quit- load + geom.
iii.   OK

Figure 2: Mesh the micro gas turbine blade

The objective of this study is to model a micro turbine compressor blade and conduct stress analysis as well as vibration analysis based on its rotation per minutes.

4.5. Materials

- Aluminum Alloy
- Stainless Steel Alloy
- Titanium Alloy

4.6. Rotational speed

- 40000 rpm
- 50000 rpm
- 60000 rpm

The outline and the examination of the structures honesty utilizing limited component strategy are directed. It is normal that the undertaking will give the proposal that can enhance the execution of blower configuration base on the past investigation.

The extent of study comprises of two noteworthy parts. The first is to outline the measurement of the blower dependent on the given yield control. The outline is relied upon to be the most ideal measurement to that proposed yield.

Table 2: Different Material and Its Details

Materials	Items	Parameter	Value
Titanium Alloy Ti-b-120UCA	Elastic Modulus	E(MPa)	0.102E6
	Poisson Ratio	N	0.3
	Density	ρ(kgm3)	4850
	Ultimate Tensile Strength	UTS(MPa)	1675
Aluminum Alloy Al-a7079	Elastic Modulus	E(MPa)	0.717E5
	Poisson Ratio	N	0.33
	Density	ρ (kgm3)	2740
	Ultimate Tensile Strength	UTS(MPa)	558
Stainless Steel Alloy 304	Elastic Modulus	E(MPa)	0.193E6
	Poisson Ratio	N	0.29
	Density	ρ (kgm3)	8030
	Ultimate Tensile Strength	UTS(MPa)	1147

5. Meshing of the solid model

5.1. Element type selection

Element types used in ANSYS may be described in terms of their shape and degree of freedom. Total number of degree of freedom gives the stiffness matrix. Common types of elements used in ANSYS are given below:

5.2. Procedure for meshing the micro turbine

i. Import the solid model from Pro/E and set the preferences for
ii. Structural analysis
iii. Plot the volumes obtained from the import option.
iv. Set the mesh options for the required size controls.
v. Then choose Volumes Mesh option and mesh the solid model
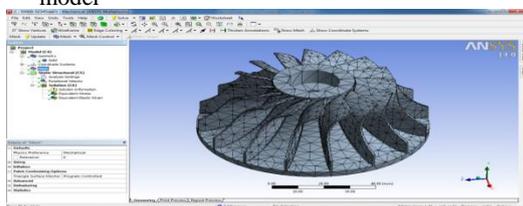
Figure 3: Meshed model of the gas turbine compressor blade

- Solid Modeling of the Piston in PRO/E
- Conversion of the solid model into finite element model
- ANSYS – Structural Analysis
- Applying Boundary conditions
- Plotting Stress Contours and Deflection Profile

5.3. Analysis result of 4000RPM stainless steel alloy 304

Here stainless steel alloy 304 as a material used for iteration it gives an stress distribution result at blade edges at 9.87 MPa and

blade face at 41.734 MPa the maximum failure occurs at join between blade and turbine face is 115.38 MPa. Stainless steel alloy 304 perform almost safe strain distribution in all area of blade except the blade joints at 4000 rpm.
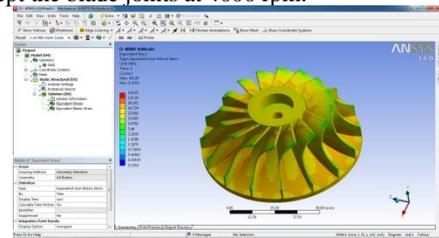

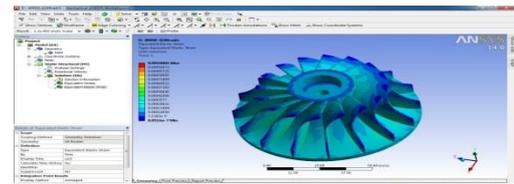**Figure 4:** Stress distribution of micro turbine compressor blade

Figure 5: Strain distribution of micro turbine compressor blade

5.4. Analysis result of 4000RPM aluminum alloy Al-A7079

Here Aluminum alloy Al-A7079 as a material used for iteration it gives an stress distribution result at blade edges at 25.29MPa and blade face at 3.283MPa the maximum failure occurs at join between blade and turbine face is.68.751MPa. Aluminum alloyal-a7079 perform almost safe strain distribution in all area of Blade except the blade joints at 4000rpm.
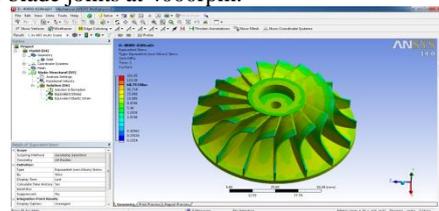

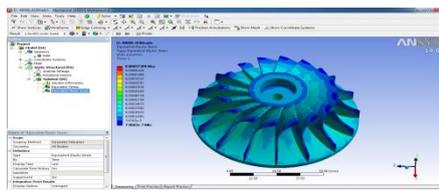**Figure 6:** Stress distribution of micro turbine compressor blade

Figure 7: Strain distribution of micro turbine compressor blade

5.5. Analysis result of 4000RPM titanium alloy TI-B-120UCA

Here Titanium alloy ti-b-120UCA as a material used for iteration it gives an stress distribution result at blade edges at 4.22MPa and blade face at 27.25MPa the maximum failure occurs at join between blade and turbine face is 46.76MPa. Titanium Alloy ti-b-120uca perform almost safe strain distribution in all area at 4000 rpm.

Table 3: Mechanical Properties of Blade Materials

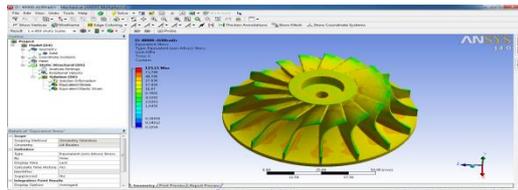| Material Properties	Stress (MPa)	Deformation (mm)
Stainless Steel	191.85	0.0010001
Aluminum Alloy	68.753	0.00097389
Titanium Alloy	115.11	0.0012052

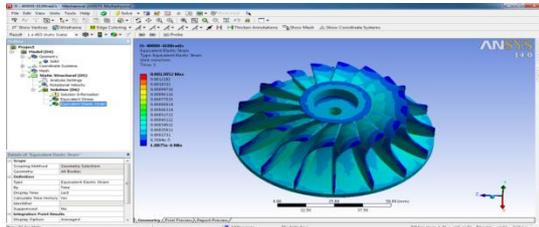**Figure 8:** Stress distribution of micro turbine compressor blade

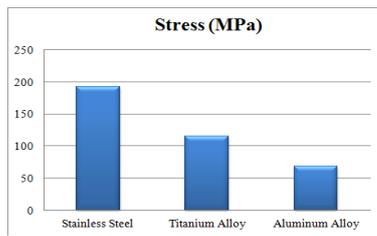**Figure 9:** Strain distribution of micro turbine compressor blade

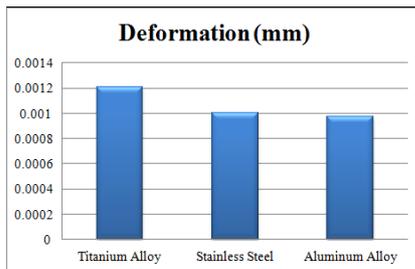**Figure 10:** Stress of different blade materials @ 40000RPM

Figure 11: Deformation of different blade materials @ 40000RPM

5.6. Analysis result of 5000RPM stainless steel alloy 304

Here Stainless steel alloy 304 as a material used for iteration it gives an stress distribution result at blade edges at 14.17MPa and blade face at 45.58MPa the maximum failure occurs at join between blade and turbine face is 100.38MPa.
Stainless Steel Alloy 304 perform almost safe strain distribution in compressor blade except the blade joints at 5000 rpm.
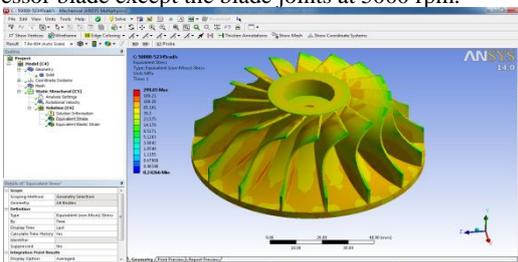
Figure 12: Stress distribution of micro turbine compressor blade
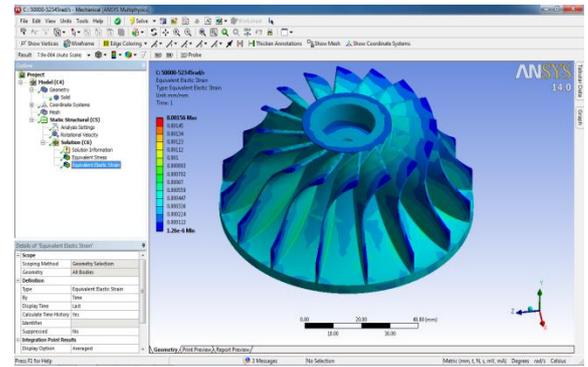
Figure 13: Strain distribution of micro turbine compressor blade

5.7. Analysis result of 4000RPM aluminum alloy Al-A7079

Here aluminum alloyal-A7079 as a material used for iteration it gives an stress distribution result at blade edges at 25.29MPa and blade face at 3.283MPa the maximum failure occurs at join between blade and turbine face is 68.751MPa.
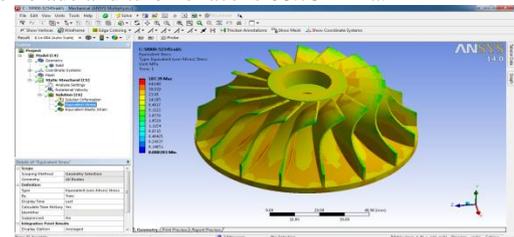
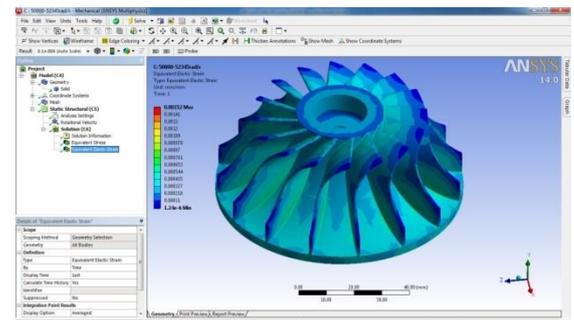**Figure 14:** Stress distribution of micro turbine compressor blade

Figure 15: Strain distribution of micro turbine compressor blade

Aluminum alloy Al-A 7079 perform almost safe strain distribution in all area of Blade except the blade joints at 5000 rpm.

5.8. Analysis result of 4000RPM titanium alloy TI-B-120UCA

Here Titanium alloy Ti-B-120UCA as a material used for iteration it gives an stress distribution result at blade edges at 4.22MPa and blade face at 27.25MPa the maximum failure occurs at join between blade and turbine face is.66.13MPa.
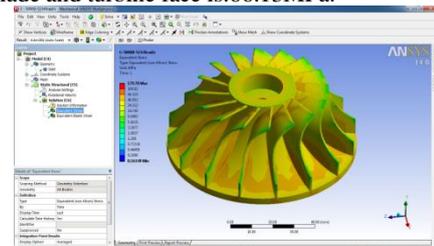

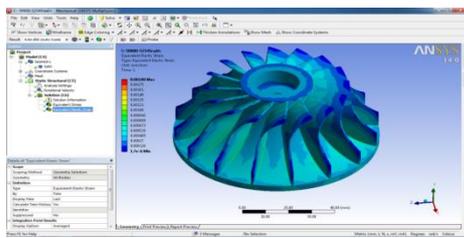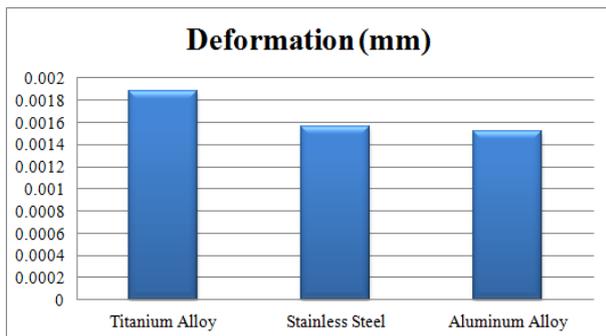**Figure 16:** Stress distribution of micro turbine compressor blade

Figure 17: Strain distribution of micro turbine compressor blade

Titanium alloy Ti-B-120UCA perform almost safe strain distribution in all area at 5000rpm.

Table 4: Mechanical Properties of Blade Materials

Material Properties	Stress (MPa)	Deformation (mm)
Stainless Steel	299.95	0.00156
Aluminum Alloy	107.39	0.00152
Titanium Alloy	179.78	0.00188
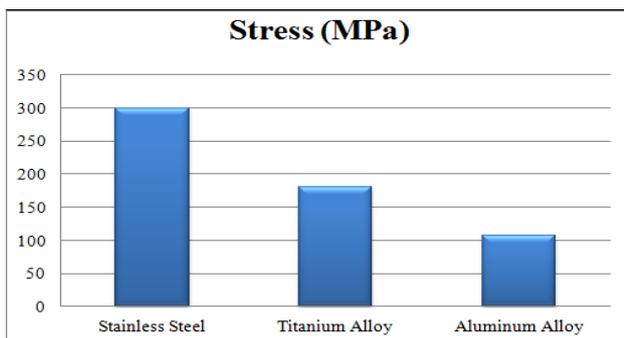
Figure 18: of Different blade materials @ 50000RPM

Figure 19: of Different blade materials @ 50000RPM

5.9. Analysis result of 6000RPM stainless steel alloy 304

Here stainless steel alloy 304 as a material used for iteration it gives a stress distribution result at blade edges at 12.29MPa and blade face at 56.49MPa the maximum failure occurs at join between blade and turbine face is 156.18.38MPa. Stainless steel alloy 304 perform almost safe strain distribution in all area of blade except the blade joints at 6000 rpm.
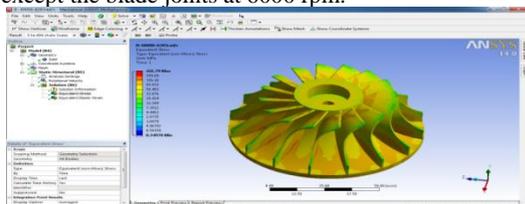

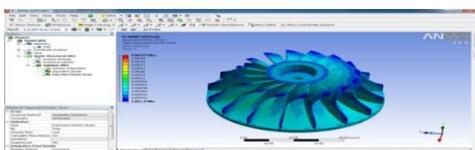**Figure 20:** Stress distribution of micro turbine compressor blade

Figure 21: Strain distribution of micro turbine compressor blade

Analysis result of 6000RPM aluminum alloy Al-A7079

Here Aluminum alloy Al-A7079 as a material used for iteration it gives an stress distribution result at blade edges at 4.47MPa and blade face at 33.78MPa the maximum failure occurs at join between blade and turbine face is.56.091MPa. Aluminum alloyAl-A7079 perform almost safe strain distribution in all area of blade except the blade joints at 6000rpm.
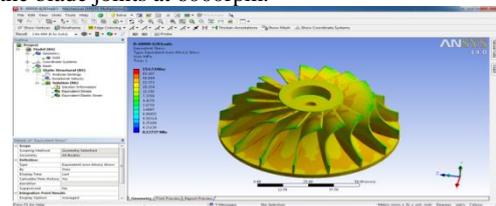

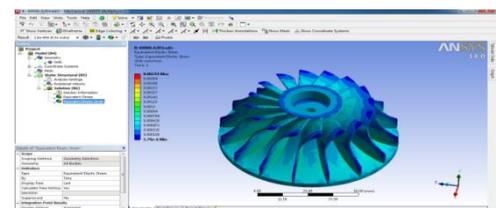**Figure 22:** Stress distribution of micro turbine compressor blade

Figure 23: Strain distribution of micro turbine compressor blade

5.10. Analysis result of 40000RPM titanium alloy TI-B-120UCA

Here Titanium alloy ti-b-120UCA as a material used for iteration it gives a stress distribution result at blade edges at 4.73 MPa and blade face at 21.25MPa the maximum failure occurs at join between blade and turbine face is.35.251MPa. Titanium alloy ti-b-120UCA perform almost safe strain distribution in all area at 6000 rpm.
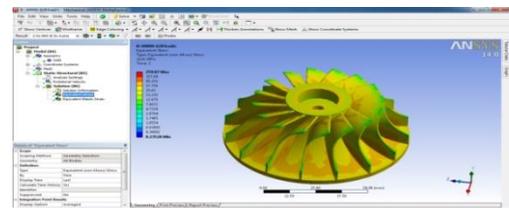

Figure 24: Stress distribution of micro turbine compressor blade

Table 5: Mechanical Properties of Blade Materials

Material Properties	Stress (MPa)	Deformation (mm)
Stainless Steel	431.79	0.00225
Aluminum Alloy	154.74	0.00219
Titanium Alloy	259.07	0.002771
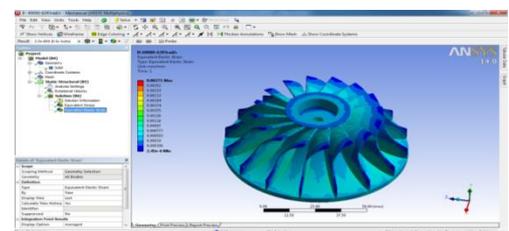
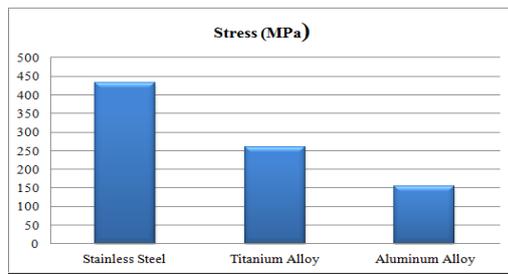**Figure 25:** Strain distribution of micro turbine compressor blade

Stress (MPa)

Figure 26: of Different blade materials @ 6000RPM
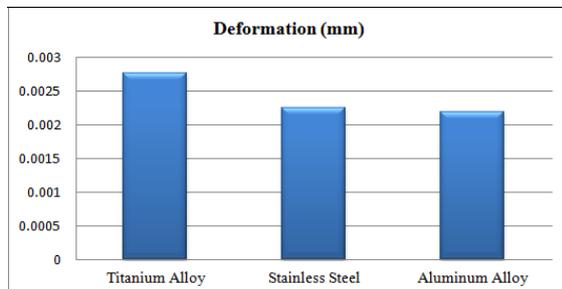
Deformation (mm)

Figure 27: of Different blade materials @ 6000RPM

6. Conclusion

Smaller scale turbines are generally new in the market and are pulling in wide consideration because of their differed applications. Improvement of an advanced designing item like small scale turbine is a nonstop procedure. A considerable measure of work is yet to be done on the plan perspectives before the miniaturized scale turbine can be prepared for market utilization. The plan method needs to take into different parameters to make it appropriate for functional applications. From the examination we infer that the aluminum amalgam perform better in every one of the 4000 rpm, 5000 rpm, 6000 rpm .so the small scale turbine blower sharp edge material is favored as Aluminum Compound A7079.

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