DESIGN OF AN AXIAL FLOW TURBOCHARGER USING FINITE ELEMENT ANALYSIS

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ABSTRACT

A turbocharger is a turbine driven forced induction device used to allow more power to be produced by an engine of a known size. A turbocharged engine can be extra powerful and efficient than a naturally aspirated engine because the turbine forces extra air, and proportionately extra fuel, into the combustion chamber than atmospheric pressure alone.

Turbocharging increases the power output from reciprocating engines by utilizing the waste energy in the exhaust gases. The exhaust gases drive a turbine, connected via a shaft to a compressor, which pressurizes the air at the engine inlet thus allowing more fuel to be burned for the same air/fuel ratio. The exhaust from the cylinders passes through the turbine blades, causeof the turbine to spin. The more exhaust that goes during the blades, the faster they spin. On the other end of the shaft that the turbine is connected to the compressor pumps air into the cylinders. The compressor was a centrifugal pump type-- it draws air in at the center of its blades and flings it outward as it spins.

Turbochargers allow an engine to burn more fuel and air by packing more into the existing cylinders. The typical improvement is provided by a turbocharger is 6 to 8 pounds per square inch (psi). Since normal atmospheric pressure is 14.7 psi at sea level the engine is getting about 50 percent more air. Therefore, 50 percent of more power is expected in the engine. It's not perfectly efficient, so 30- to 40-percent improvement instead is expected.

In this project, a turbo charger used in a car is designed and modeled in 3D modeling software Pro/Engineer. Coupled Field analysis (Structural + Thermal) is done on the turbo charger by changing the materials of the turbine blade while car is running at higher speeds. Analysis is done in Ansys.

The present used material for blade is Steel. In this we are replacing with Titanium alloy and Nickel alloy. Coupled field analysis is done on two blades.

CFD analysis is done on the turbocharger turbine blades, 10 and 11 by applying inlet velocity of 90m/s and on the compressor by applying 80m/s.

I. INTRODUCTION TO ENGINES

An engine or motor is a machine designed to convert energy into required mechanical motion. Heat engines areincluding internal burning engines and external burning engines (such as steam engines) burn a fuel to generate heat, which then generates motion. Electric motors convert electrical energy into mechanical movement, pneumatic motors are use to compressed air and others—such as clockwork motors in wind-up toys—use of elastic energy. In biological system, molecular motors, like myosins in muscles, use of chemical energy to create motion.

II. ENGINE OPERATION

Engines are two types based on strokes. The working depends on number of running strokes. They are

- Two stroke engine
- Four stroke engine

2.1 Two-Stroke

This system manages to pack one power stroke into every two strokes of the piston (up-down). This is achieved by exhausting and recharging the cylinder simultaneously.

2.1.1 The Steps Involved Here Are

Intake and exhaust occur at bottom dead center. Some type of pressure is needed, either crankcase density or super-charging.

2.1.2 Compression stroke

Fuel-air mix is compressed and ignited. In case of diesel: Air was compressed, fuel is injected and self-ignited.

2.1.3 Power Stroke

Piston is pushed downstairs by the hot exhaust gases.

2.1.4 Two Stroke Spark Ignition (SI) Engine

In a two-stroke SI engine a cycle is completed in two strokes of a piston or one complete revolution (360°) of a crankshaft. In this type of engine the intake and exhaust strokes are eliminated and ports are used as a substitute of valves. In this cycle, the gasoline is assorted with lubricant oil, resulting in a simpler, but additional environmentally damaging system, as the overkill oils do not burn and are left asremains. As the piston proceeds downstairs another port will be opened, the fuel/air intake port. Air/fuel/oil mixtures appear from the carburetor, where it was mixed, to rest in anext fuel chamber. When the piston moves advance down and the cylinder doesn't have any more gases, fuel mixture starts to flow to the burning chamber and the second process of fuel compression starts. The design suspiciously considers the point that the fuel-air mixture should not mix with the exhaust, therefore the fuel injection processes and exhausting are synchronized to avoid that concern.

Functions of Piston in the Operation:

- With the help of cylinder this piston acts as combustion chamber and compresses the air/fuel mixture, receives back the liberated energy and this energy will be transferred to the crankshaft.

- The piston movement creates a vacuum and its sucks the fuel/air mixture from the carburetor then pushes it from the crankcase (adjacent chamber) to the combustion chamber.
- The sides of the piston works like a valves, covering and uncovering the intake and exhaust ports drilled into the side of the cylinder wall.

The major elements of a two-stroke spark ignition engine are the:

Cylinder: It is a cylindrical vessel in which a piston makes an up and down motion.

Piston: It was an cylindrical component making an up and down movement in the cylinder

Combustion chamber: It was a portion above the cylinder in which the combustion of the fuel-air mixture takes place

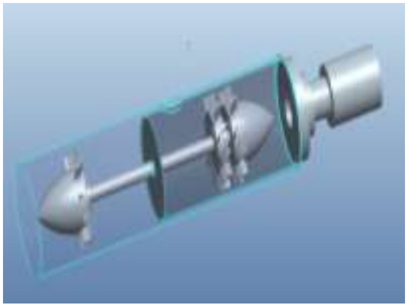
Intake and exhaust ports:these will carry fresh fuel-air mixture into the combustion chamber and products of combustion away

Crankshaft: This helps to converts reciprocating motion of the piston into rotary motion

Connecting rod:which helps to connects the piston to the crankshaft

Spark plug:the process of combustion is takes place by an ignition-source in the cylinder head

2.2 Assembly



Material Properties

Element Type: solid 20 nodes 95

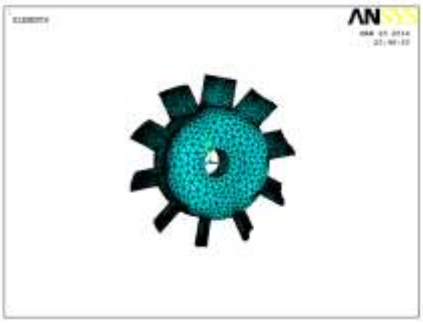
Material Properties: Density – 0.00000443Kg/mm3

Young's Modulus – 113800Mpa

Poisson's ratio - 0.342

Physics Environment Write- Structural-ok

Read Thermal-ok

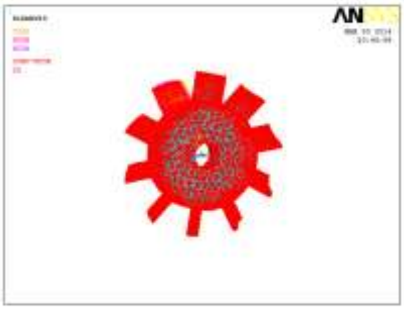


2.3 Loads

Define Loads -Apply Thermal-Temperature- on Area=623K

Convections – on Area-Film Co-efficient – 25 W/mmK

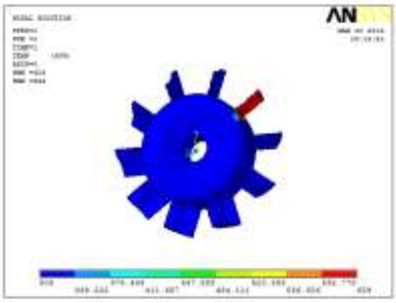
Bulk Temperature –303 K



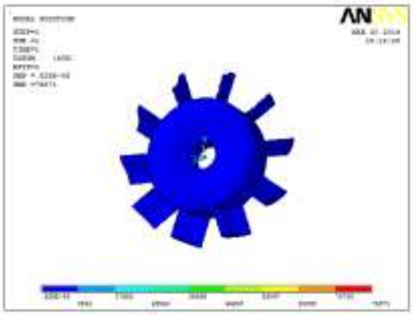
Solution – Solve - Current LS file – Ok

2.4 Results

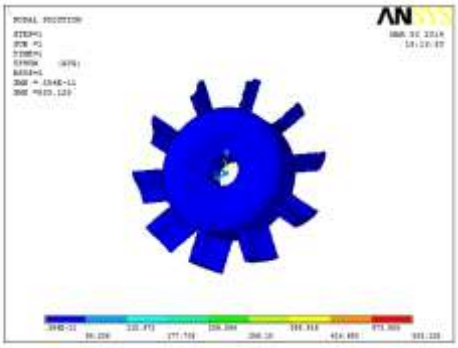
General post processer- contour plot- nodal solution- Nodal Temperature



General post processer- contour plot- Thermal Gradient-Thermal Gradient Vector Sum



General post processer- contour plot-Thermal Flux –Thermal Flux Vector Sum



Again Preferences

Physics --Read -Structural -ok

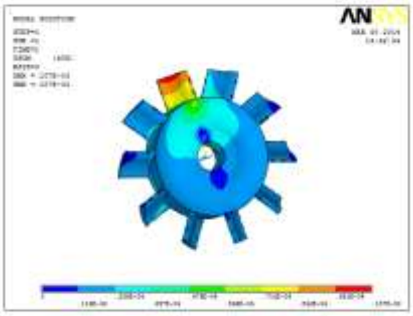
Preprocessor Loads Define Loads by Apply Structural displacement On Areas

Select Areas ok

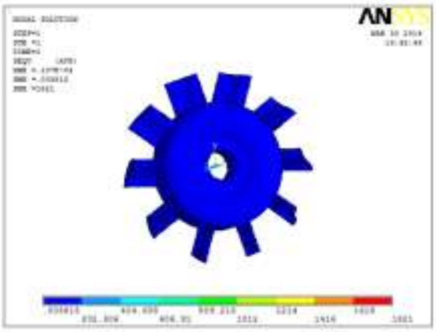
Pressure On areas select areas-ok

Solution solve current L.S-ok

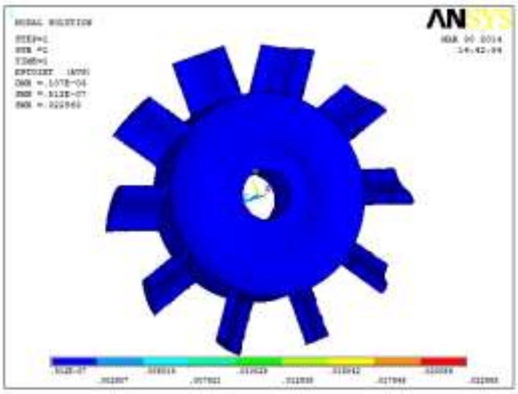
General post processer- contour plot- nodal solution- Displacement vector sum



General post processer- contour plot-Stress-Von Misses Stress



General post processer- contour plot-Strain- Total Strain Intensity



III. NICKEL ALLOY

Set Units - /units,si,mm,kg,sec,k

File- change Directory-select running folder

File-Change job name-Enter job name

Preferences – thermal

Select element-Solid20 Node 95

IV. MATERIAL PROPERTIES

Specific Heat Capacity 0.435 J/g-°C

Thermal Conductivity 11.40 W/m-K

Density – 8.19 g/cc

Meshed Model

Select Mesh Tool Icon – Select Smart Size –On

Select Mesh Tool Window –Select All Areas –pick all-close

Physics-Environment- Write-Thermal –Ok

Again Preferences- structural-ok

Preprocessor-element Type Switch element type-thermal to structural-ok

Material Properties

Element Type: solid 20 nodes 95

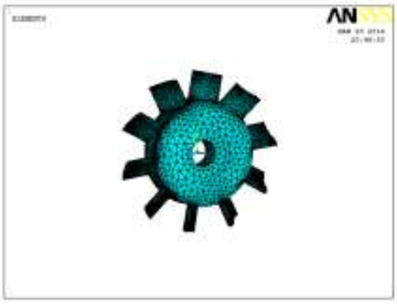
Material Properties: Density – 0.00000819Kg/mm3

Young's Modulus – 205000Mpa

Poisson's ratio - 0.284

Physics Environment Write- Structural-ok

Read Thermal-ok

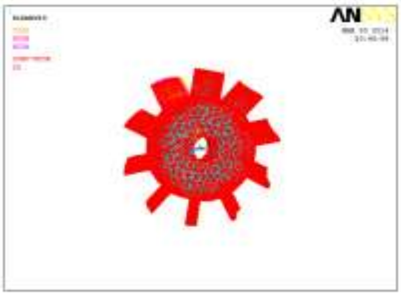


4.1 Loads

Define Loads -Apply Thermal-Temperature- on Area=623K

Convections – on Area-Film Co-efficient – 25 W/mmK

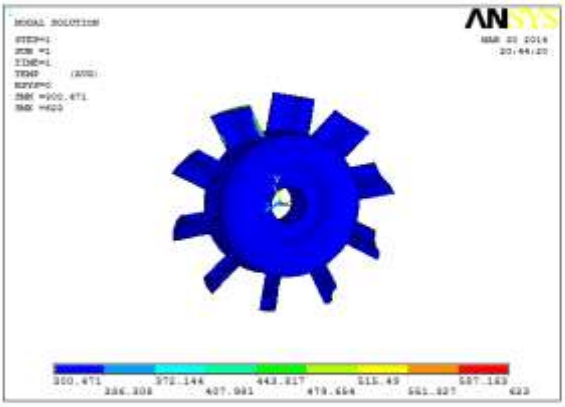
Bulk Temperature –303 K



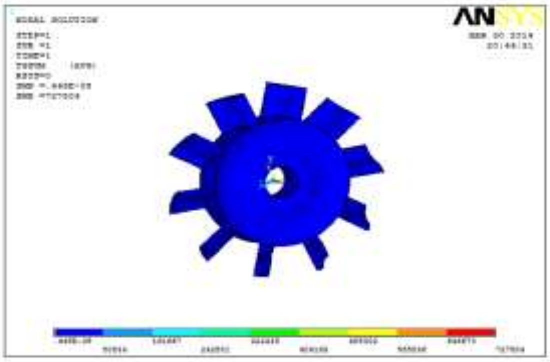
Solution – Solve - Current LS file – Ok

4.2 Results

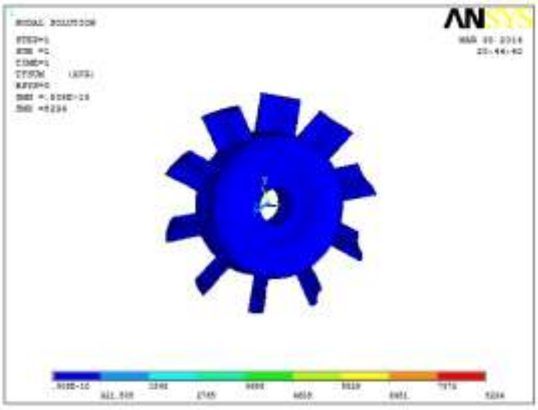
General post processer- contour plot- nodal solution- Nodal Temperature



General post processer- contour plot- Thermal Gradient-Thermal Gradient Vector Sum



General post processer- contour plot-Thermal Flux –Thermal Flux Vector Sum



Again Preferences

Physics --Read -Structural -ok

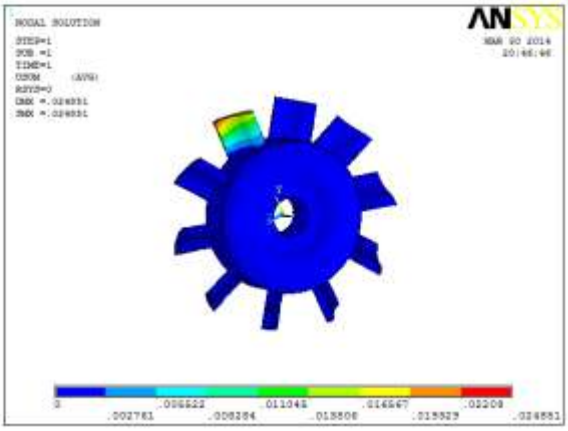
Preprocessor Loads Define Loads by Apply Structural displacement On Areas

Select Areas ok

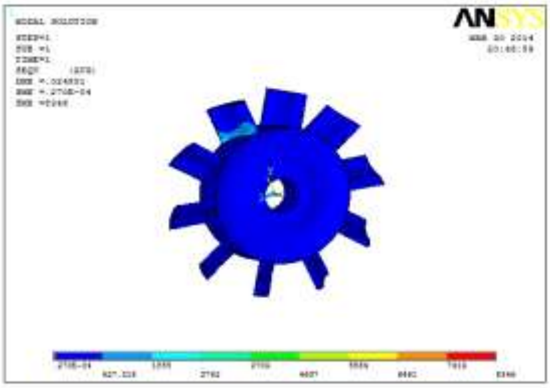
Pressure On areas select areas-ok

Solution solve current L.S-ok

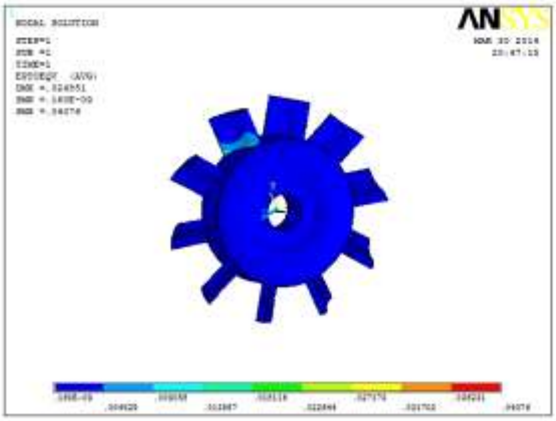
General post processer- contour plot- nodal solution- Displacement vector sum



General post processer- contour plot-Stress-Von Misses Stress



General post processer- contour plot-Strain- Total Strain Intensity

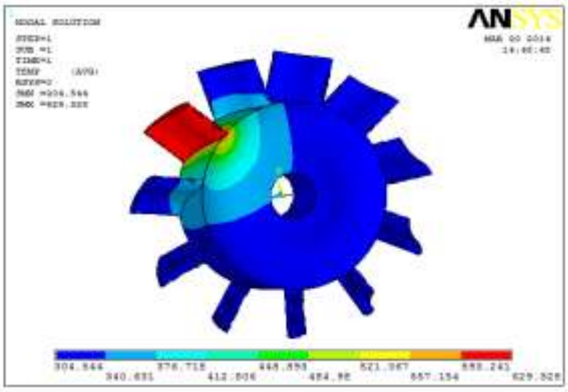


11 BLADES

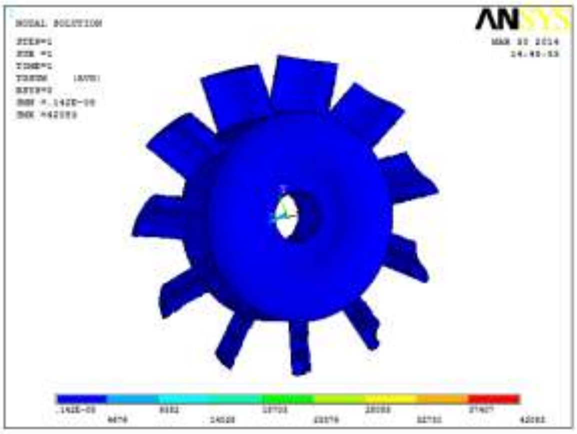
TITANIUM ALLOY

4.3 RESULTS

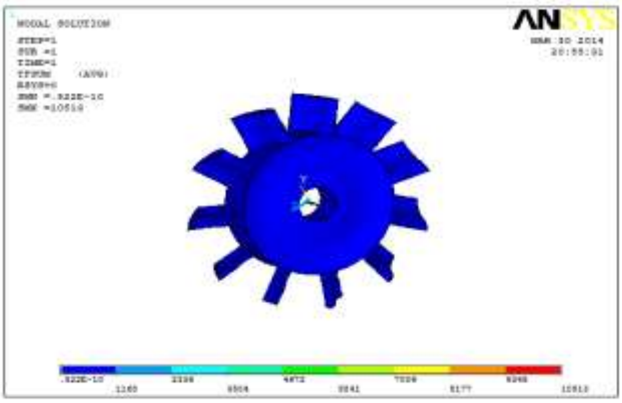
General post processer- contour plot- nodal solution- Nodal Temperature



General post processer- contour plot- Thermal Gradient-Thermal Gradient Vector Sum



General post processer- contour plot-Thermal Flux –Thermal Flux Vector Sum



Again Preferences

Physics --Read -Structural -ok

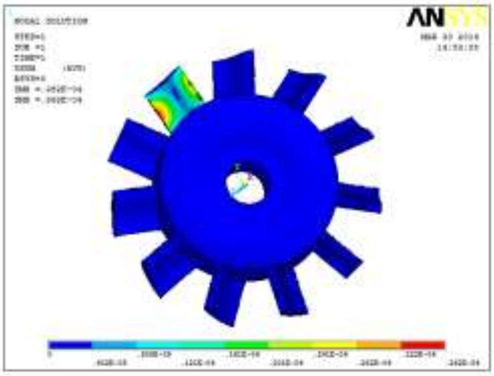
Preprocessor Loads Define Loads by Apply Structural displacement On Areas

Select Areas ok

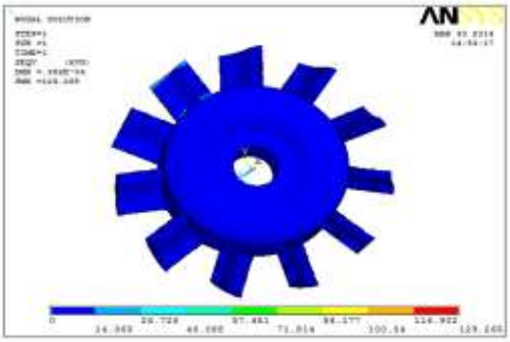
Pressure On areas select areas-ok

Solution solve current L.S-ok

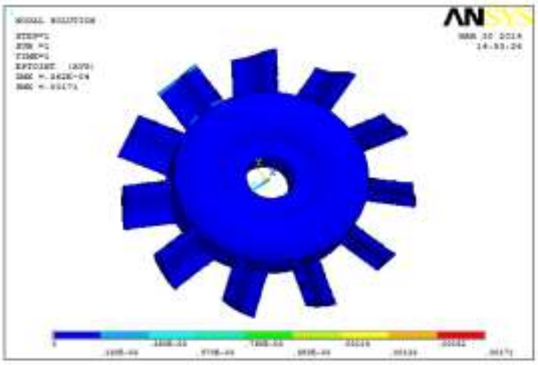
General post processer- contour plot- nodal solution- Displacement vector sum



General post processer- contour plot-Stress-Von Misses Stress

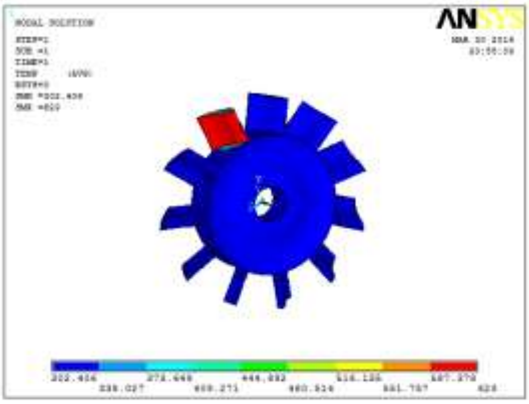


General post processer- contour plot-Strain- Total Strain Intensity

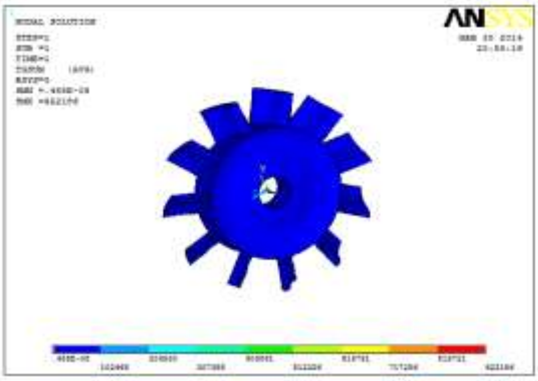


4.4 Nickel Alloy

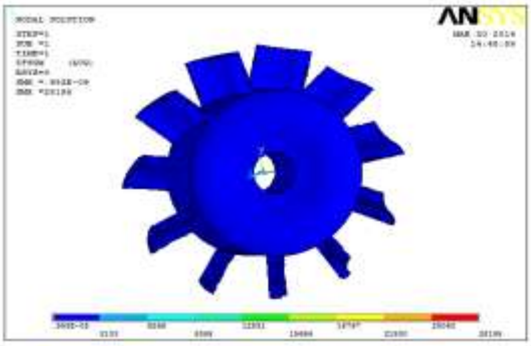
General post processer- contour plot- nodal solution- Nodal Temperature



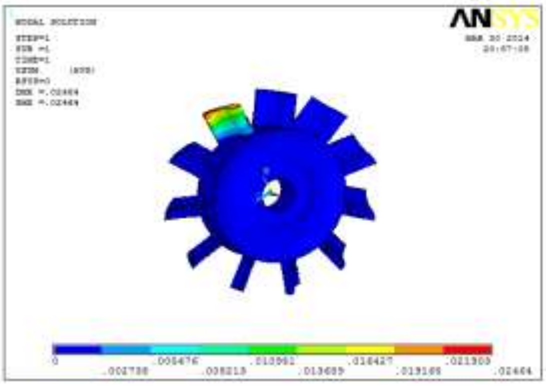
General post processer- contour plot- Thermal Gradient-Thermal Gradient Vector Sum



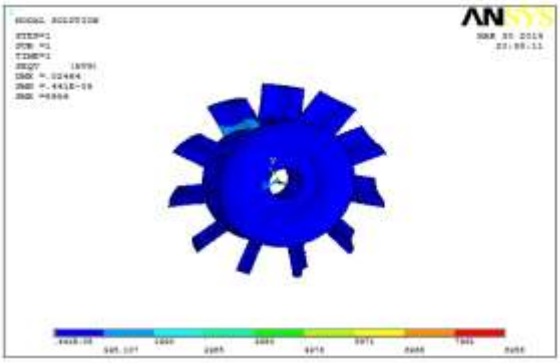
General post processer- contour plot-Thermal Flux –Thermal Flux Vector Sum



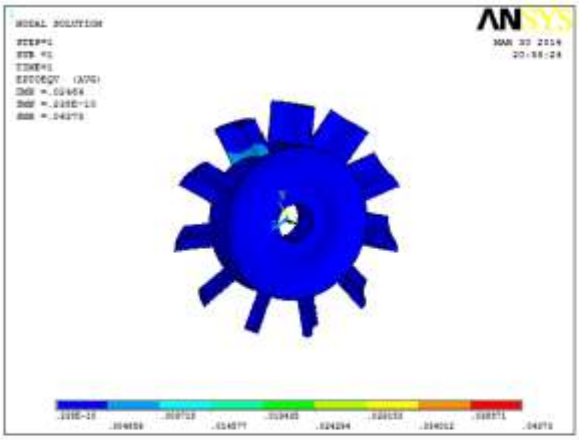
General post processer- contour plot- nodal solution- Displacement vector sum



General post processer- contour plot-Stress-Von Misses Stress



Total Strain Intensity



V. RESULTS TABLE

10 BLADES

	TITANIUM ALLOY	NICKEL ALLOY
Temperature (K)	621	623
Thermal Gradient (K/mm)	79571	727504
Heat Flux (W/mm^2)	533.125	8294
Displacement (mm)	0.00107	0.024851
Stress (N/mm^2)	1821	8346
Strain	0.022563	0.04076

11 BLADES

	TITANIUM ALLOY	NICKEL ALLOY
Temperature (K)	629.38	623
Thermal Gradient (K/mm)	42083	922186
Heat Flux (W/mm^2)	10513	28195
Displacement (mm)	0.000362	0.02464
Stress (N/mm^2)	129.265	8956
Strain	0.00171	0.04272

VI. CFD ANALYSIS OF BLADES

10 BLADES

→→Ansys → workbench→ select analysis system → fluid flow fluent → double click

→→Select geometry → right click → import geometry → select browse →open part → ok

→→ select mesh on work bench → right click →edit → select mesh on left side part tree → right click → generate mesh →

Select faces → right click → create named section → enter name → air inlet

Select faces → right click → create named section → enter name → air outlet

File export → fluent →input file(mesh) → save required name → save.

→→ ansys → fluid dynamics → fluent → select working directory → ok

→→file → read → mesh → select file → ok.

General →Pressure based

Model → energy equation → on.

Viscous → laminar

Materials → new → create or edit → specify fluid material or specify properties → ok

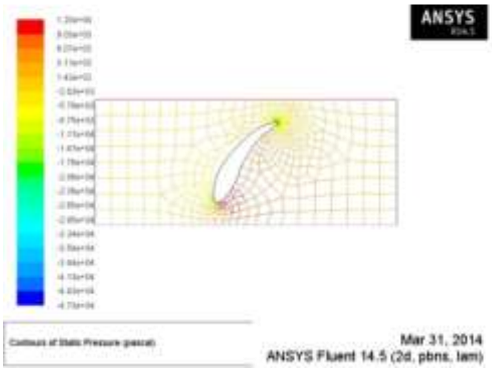
Select air Boundary conditions → select air inlet → Edit → Enter Inlet Velocity → 9071m/s and Inlet Temperature – 550K

Solution → Solution Initialization → Hybrid Initialization →done

Run calculations → no of iterations = 10 → calculate → calculation complete

→→ **Results → graphics and animations → contours → setup**

Static Pressure



Static Temperature

5.1 VELOCITY

	10 Blades	11 Blades	Compressor
Pressure (Pa)	1.20e+04	1.67e+04	9.48e+03
Temperature (K)	5.50e+02	5.50e+02	4.000e+02
Velocity (m/s)	2.94e+02	3.00e+02	2.62e+02
Mass flow rate (kg/s)	0.00032520294	1.1632219e-06	0.00028276443
Heat Transfer rate (w)	82.625	93.6	29.0625

5.2 COUPLED FIELD ANALYSIS RESULTS TABLE

10 BLADES

	TITANIUM ALLOY	NICKEL ALLOY
Temperature (K)	621	623
Thermal Gradient (K/mm)	79571	727504
Heat Flux (W/mm^2)	533.125	8294
Displacement (mm)	0.00107	0.024851
Stress (N/mm^2)	1821	8346
Strain	0.022563	0.04076

11 BLADES

	TITANIUM ALLOY	NICKEL ALLOY
Temperature (K)	629.38	623
Thermal Gradient (K/mm)	42083	922186
Heat Flux (W/mm^2)	10513	28195
Displacement (mm)	0.000362	0.02464
Stress (N/mm^2)	129.265	8956
Strain	0.00171	0.04373

VI. CONCLUSION

In this project, we have designed a turbo charger used in a Skoda Rapid and modeled in 3D modeling software Pro/Engineer.

Coupled Field analysis (Structural + Thermal) is done on the turbo charger by changing the materials of the turbine blade while car is running at higher speeds. Analysis is done in Ansys.

The present used material for blade is Steel. In this we are replacing with Titanium alloy and Nickel ally. Coupled field analysis is done on two blades.

By comparing the thermal analysis results, the heat transfer rate is more for Nickel Alloy than Titanium alloy. But by considering structural analysis results, the stresses are less for Titanium alloy than Nickel alloy. And also by using Nickel alloy, the weight is more.CFD analysis is done on the turbocharger turbine blades, 10 and 11 by applying inlet velocity of 90m/s and on the compressor by applying 80m/s.

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