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Computational Turbine Blade Analysis with Thermal Barrier Coating

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ABSTRACT:
Thermal barrier coatings (TBCs) are widely applied in protecting metallic components, which are used in aero- and land-based gas turbines. These hot-section components include combustion chamber, blades, and vanes. The TBC leads to significant reduction of heat transfer from the high temperature gas to metal surface. As a result, with increase of operating temperature inside the gas turbines, their efficiency would be improved notably. Typically, a TBC system exhibits multilayer added structure, consisting of a bond coat and a top coat. Thermal barrier coatings are advanced materials systems usually applied to metallic surfaces operating at elevated temperatures, such as gas turbine or aero-engine parts, as a form of exhaust heat management. The ANSYS WORKBENCH is used to do the static structural & steady state thermal anlysis of the gas turbine blades and CATIA is used to develop the model of the turbine blade. CFM 56 7B series turbofan engine(B737) is considered for the study ,which consists of a 4 stage low pressure turbine and a single stage high pressure turbine.

KEY WORDS: turbine blade , Thermal coating , high temperature, blade cooling

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I. INTRODUCTION :

For this purpose many researches are going on about the turbine blade materials and they have developed the thermal barrier coatings for turbine blades . Researches shows that the TBC provides protection against the oxidation and hot corrosion from high temperature gases. Some of the benefits of thermal barrier coating are: reduction of maintenance costs, increase of the working temperature, reduction of thermal loads, resistance increase to erosion and corrosion and reduction of the high temperature oxidation.

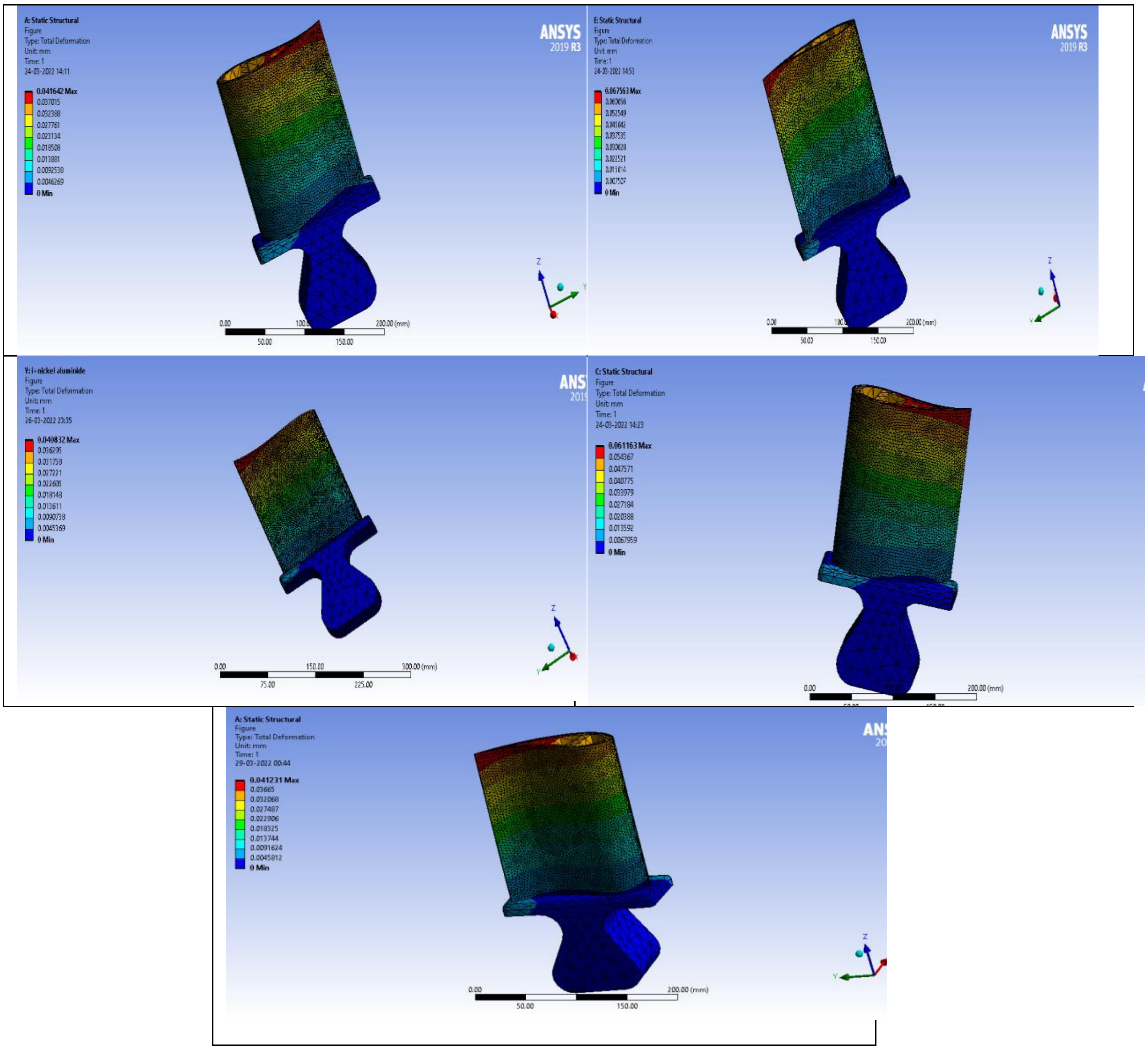
TBC are highly advanced materials applied to metallic surfaces, which operating at elevated temperatures and can allow higher operating temperatures & limits the thermal exposure of structural components and thus extends the parts life.

In advanced aero engines , thermal barrier coating technology is listed as one of the three key technologies for advanced aero-engine turbine blades with high temperature structural materials and high efficiency air cooling. It utilizes ceramic materials with high temperature resistance and low thermal conductivity to be combined with metal ,which can effectively reduced the surface temperature of the metal in a high temperature environment, thereby greatly extending the working life of metal parts.

STATIC STRUCTURAL ANLYSIS

A static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Static structural analyses are used for simple linear calculations as well as complex material, geometric and contact nonlinear calculations. The analysis results help to identify weak areas with low strength and durability.

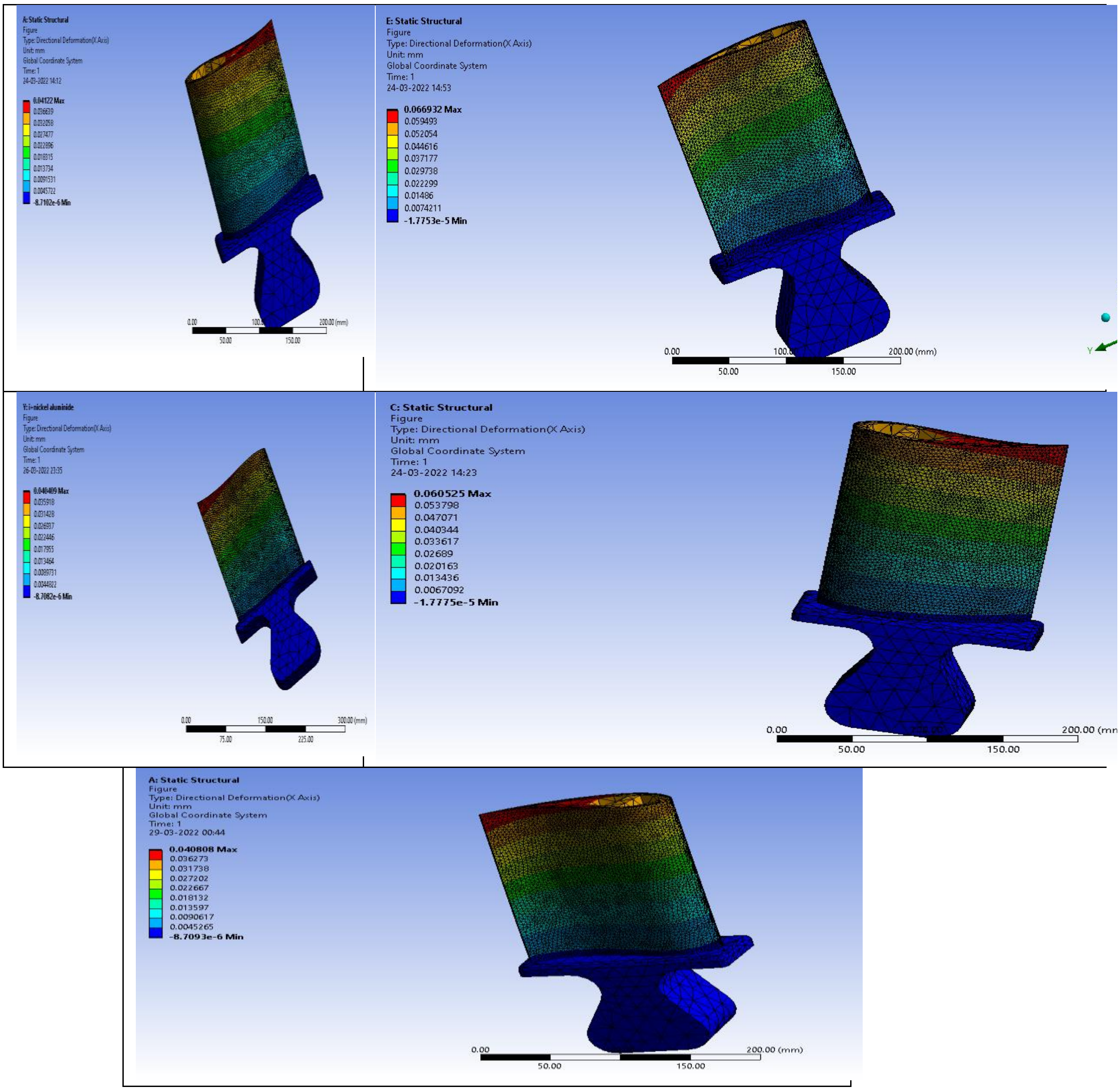
TOTAL DEFORMATION
BLADE ANALYSIS OF TURBINE BLADE WITH COATING



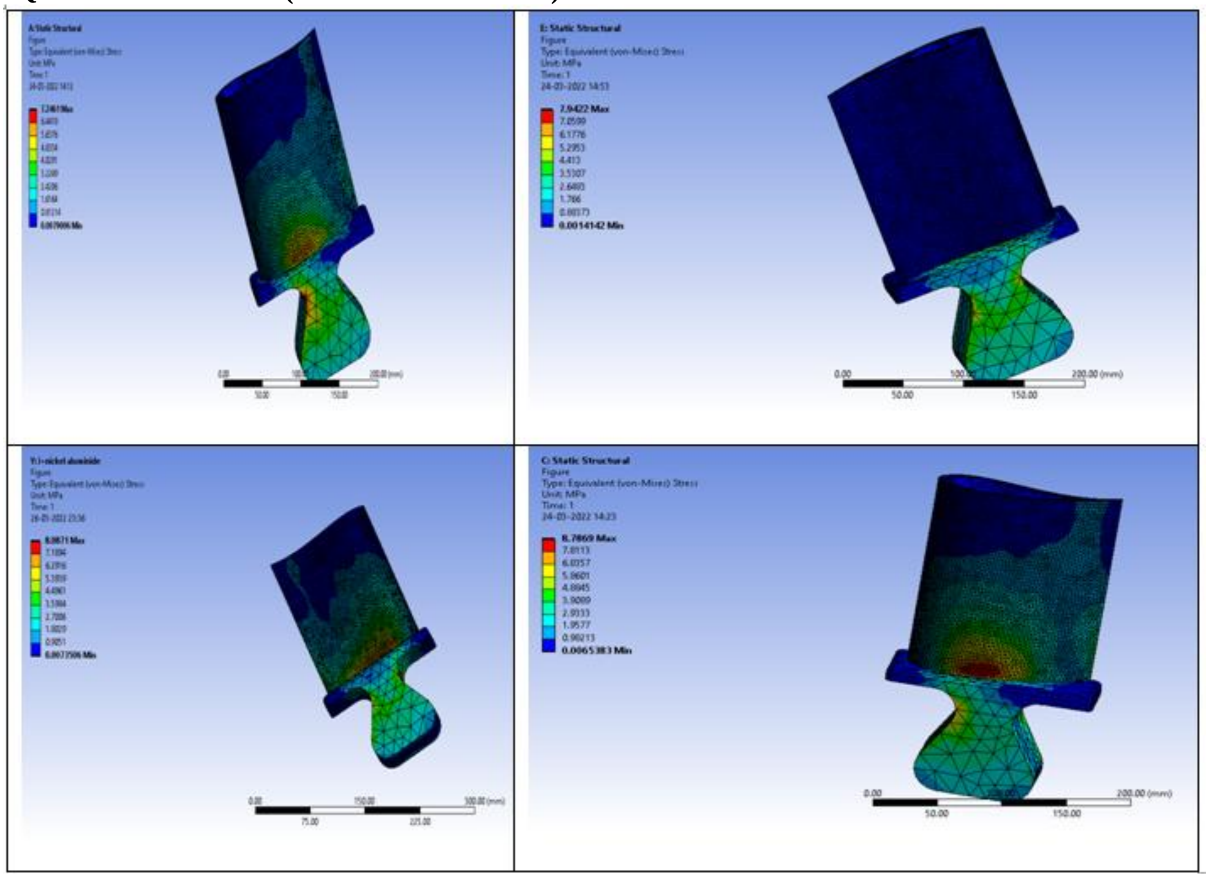
a) Inconel 625+ Zirconium oxide b) Ti6Al4v + Silicon carbide c) Inconel 625+Nickel Aluminide d) Ti6Al4v + Zirconium oxide e) Inconel 625+Zirconium silicate

DIRECTIONAL DEFORMATION

a) Inconel 625+ Zirconium oxide b) Ti6Al4v + Silicon carbide c) Inconel 625+Nickel Aluminide d) Ti6Al4v + Zirconium oxide e) Inconel 625+Zirconium silicate

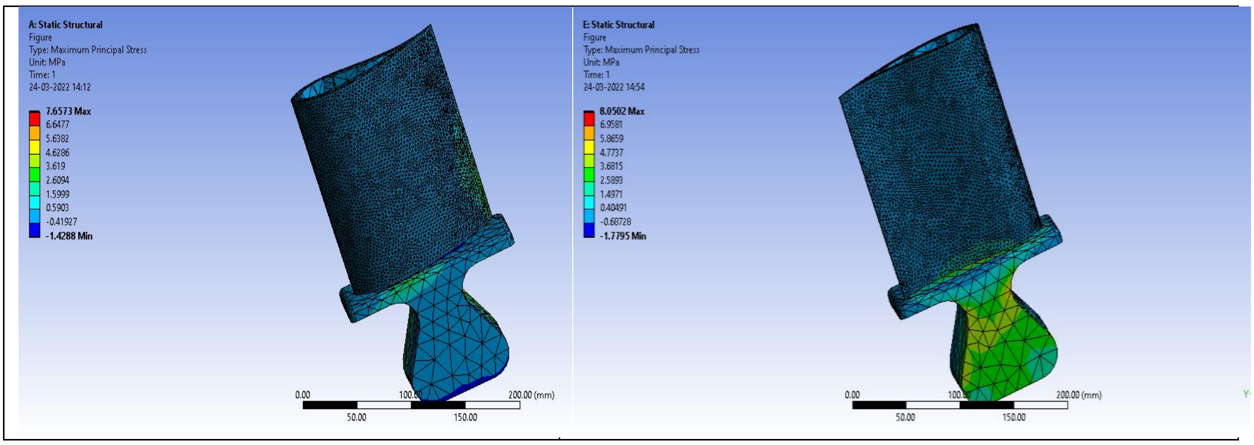


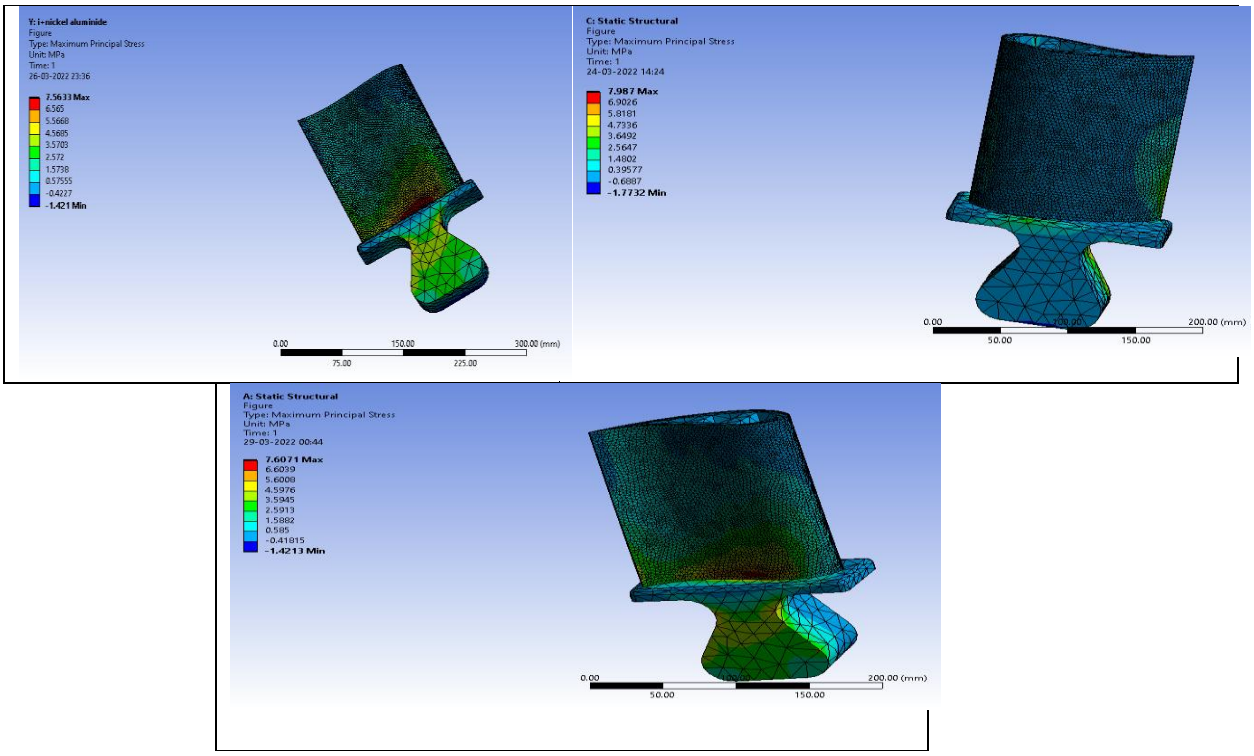
EQUIVALENT STRESS(VON-MISES STRESS)



a) Inconel 625+ Zirconium oxide b) Ti6Al4v + Silicon carbide c) Inconel 625+Nickel Aluminide d) Ti6Al4v + Zirconium oxide e) Inconel 625+Zirconium silicate

MAJOR PRINCIPAL STRESS





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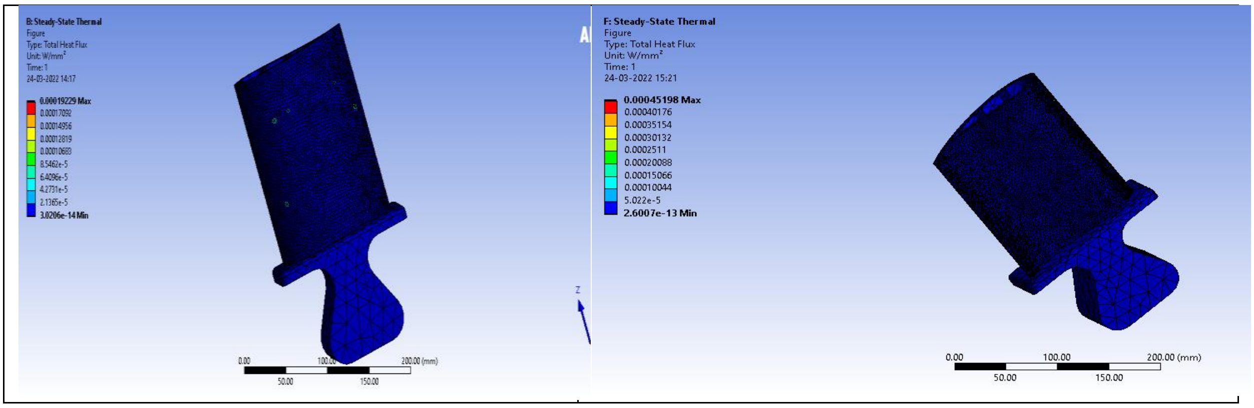
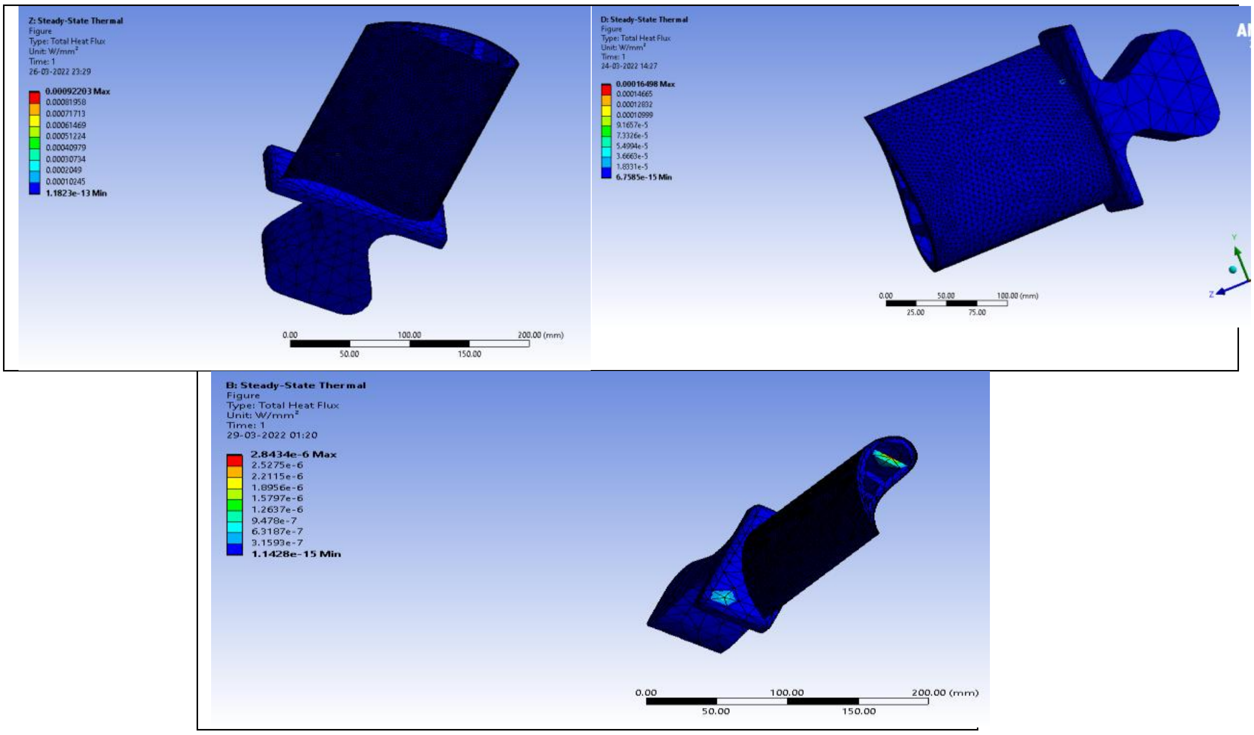
STEADY STATE THERMAL ANALYSIS

Steady-state thermal analysis is evaluating the thermal equilibrium of a system in which the temperature remains constant over time. In other words, steady-state thermal analysis involves assessing the equilibrium state of a system subject to constant heat loads and environmental conditions.For many simulations ,steady state thermal analysis can be used to design and evaqluate systems,even throughout the final stages of design process.

Heat flux (Φ) can be defined as the rate of heat energy transfer through a given surface (W), and heat flux density (φ) is the heat flux per unit area (Wm²). Heat can flow through solid materials (in which case it is called conduction), through gases and liquids (which is called convection) and through electromagnetic waves (which is called radiation). Heat Flux depends on the temperature difference and the thermal transfer coefficient.

TOTAL HEAT FLUX





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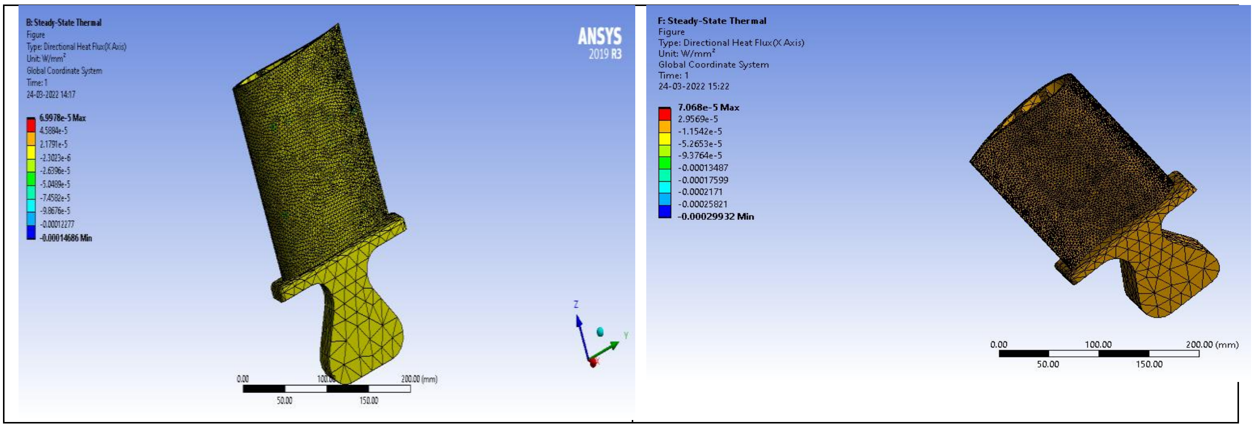
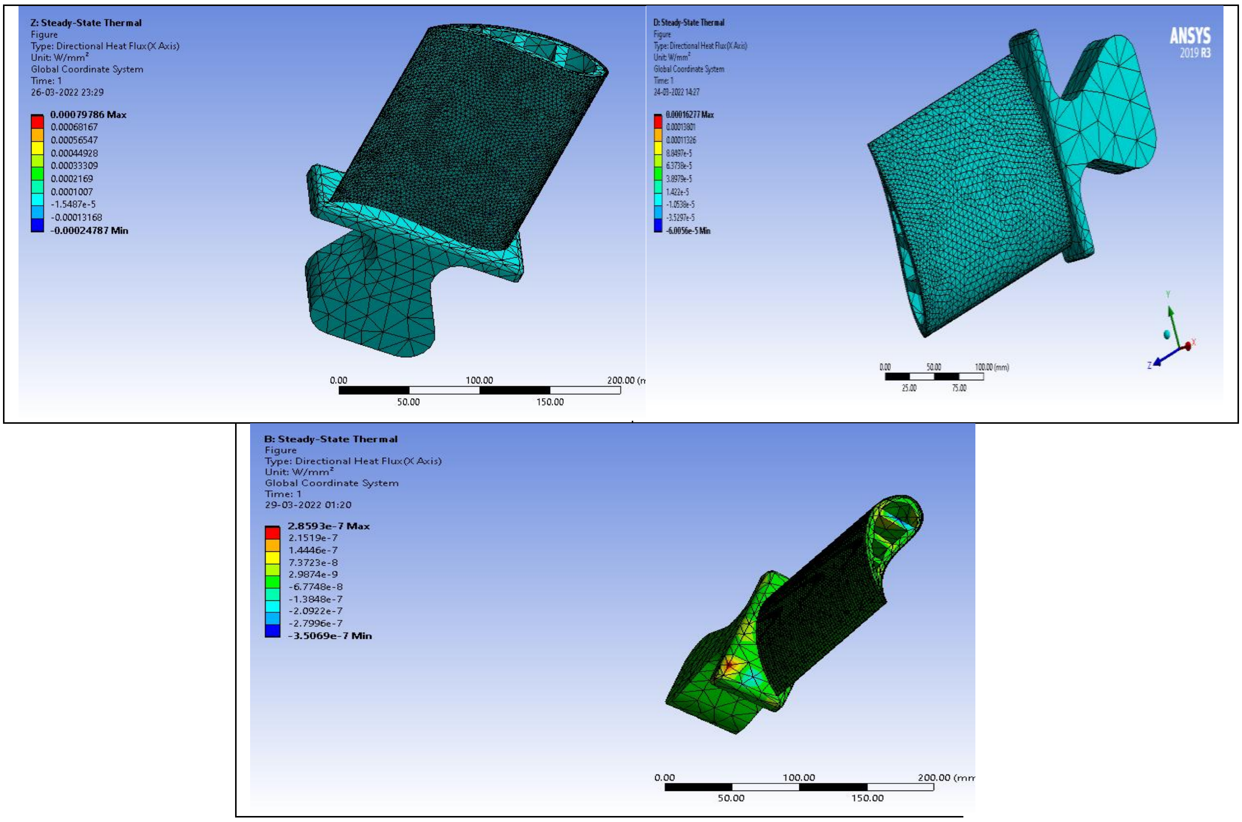
DIRECTIONAL HEAT FLUX





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II. RESULT AND DISCUSSION :

Materials	Total deformation (mm)	Directional Deformation (mm)	Equivalent Stress(MPa)	Maximum Principal Stress(MPa)
Ti6Al4v + zirconium oxide[TBC]	0.061163	0.060525	8.7869	7.987
Inconel 625 +Zirconium silicate[TBC]	0.041231	0.040808	7.2482	7.6071
Ti6Al4v + silicon carbide[TBC]	0.067563	0.066932	7.9422	8.0502
Inconel 625 + zirconium oxide [TBC]	0.041642	0.04122	7.2461	7.6573
Inconel 625 + Nickel aluminide[TBC]	0.040832	0.040409	8.0871	7.5633

Materials	Total heat flux(w/mm2)	Directional heat flux (w/mm2)
Ti6Al4v + zirconium oxide[TBC]	0.00016498	0.00016277

Inconel 625 +Zirconium silicate[TBC]	2.8434e-6	2.8593e-7
Ti6Al4v + silicon carbide[TBC]	0.00045198	7.068e-5
Inconel 625 + zirconium oxide [TBC]	0.00019229	6.9978e-5
Inconel 625 + Nickel aluminide[TBC]	0.00092203	0.00079786

II. CONCLUSION:

After evaluating its results the coating materials such as SILICON CARBIDE,NICKEL ALUMINIDE,ZIRCONIUM OXIDE,ZIRCONIUM SILICATE is added along with the blade materials such as INCONEL 625& Ti6Al4V and did static structural & steady state thermal analysis. The results have proven that the application of coating materials reduced the deformation, stresses & heat fluxes forms in turbine blades. So from the conducted study it is concluded that the application of thermal barrier coatings can reduce the excess temperature problems and can increase the structural strength.

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