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Aero Elastic Analysis of a Transonic Fan Blade with Different Mach Numbers

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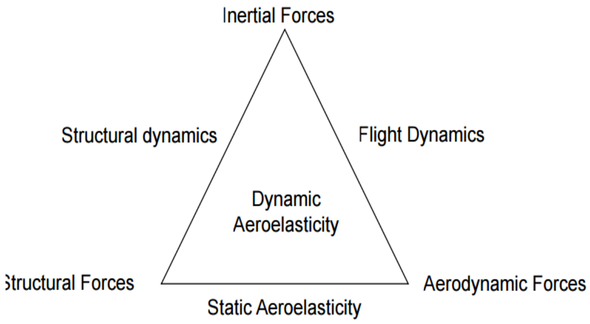
ABSTRACT:

In this thesis, the improvement of high-performance turbine airfoils is examined under the supersonic condition. Transonic turbine airfoil is designed and modeled in 3D modeling software Creo 2.0. CFD analysis is done by considering k-ε turbulence model at different velocities of air to authenticate the aerodynamic performance of turbine airfoil. The velocities of air are varied by changing the Mach number 0.8, 0.9, 1, 1.1 and 1.2. Analysis is done in Ansys.

I. INTRODUCTION

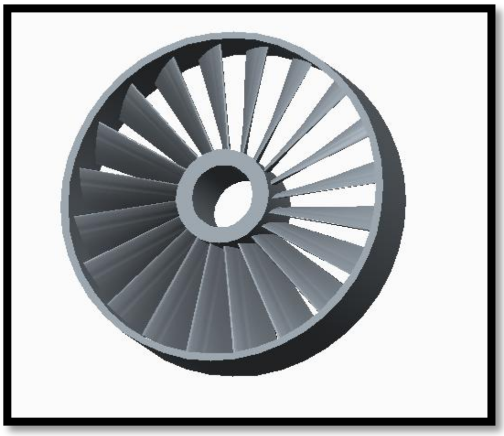
AEROELASTICITY:

• Aeroelasticity is the study of the interaction of inertial, structural and aerodynamic forces on aircraft, buildings, surface vehicles etc.



Is the division of physics and engineering that studies the interactions between the inertial, elastic, and aerodynamic forces that occur when an elastic body is exposed to a fluid flow. Although ancient studies have been focused on aeronautical applications, recent research has found applications in fields such as energy harvesting and understanding snoring. The study of aero elasticity may be generally classified into two arenas: static aero elasticity, which deals with the static or steady response of an elastic body to a fluid flow; and dynamic aero elasticity, which deals with the body's dynamic (typically vibrational) response. Aero elasticity draws on the study of fluid mechanics, solid mechanics, structural dynamics and dynamical systems. The combination of aero elasticity with thermodynamics is known as aero thermoelasticity, and its synthesis with control theory is known as aero servoelasticity.

MODELING OF AERO ELASTIC OF A TRANSONIC FAN BLADE IN CREO 2.0



Final model

ANALYSIS OF AERO ELASTIC OF A TRANSONIC FAN BLADE

BOUNDARY CONDITIONS

The aero elastic of a transonic fan Blade is inspected, the value is taken from the slandered Mach number as 0.8 to 1.2.

Velocity are taken from the formula

V = Mach number x sound velocity in air

The material properties are detailed in the below table which are taken from website www.matweb.com

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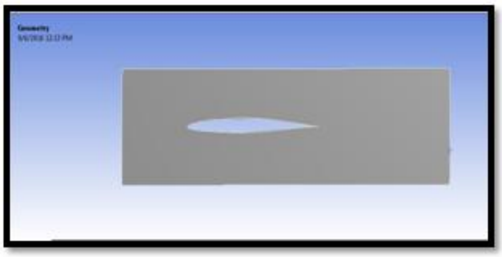
MATERIAL	Density (g/cc)	Young's modulus (GPa)	Poisson's ratio
STAINLESS STEEL	7.750	200	0.29
ALUMINUM ALLOY2024	2.78	73.1	0.33

Table -1 Material Property

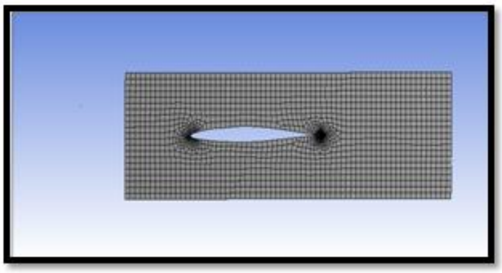
CFD ANALYSIS OF AERO ELASTIC OF A TRANSONIC FAN BLADE

Mach number - 0.8
Velocity – 274.56 m/s

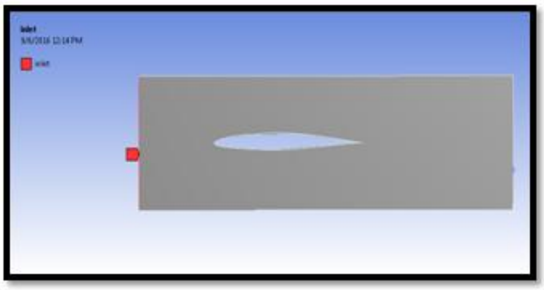
Imported model



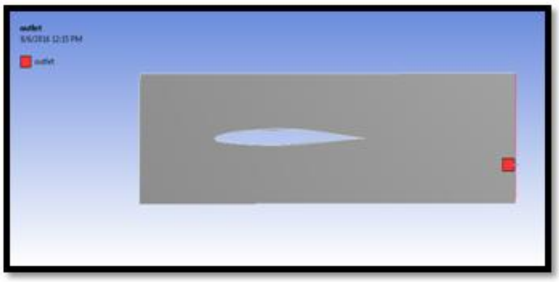
Meshed model



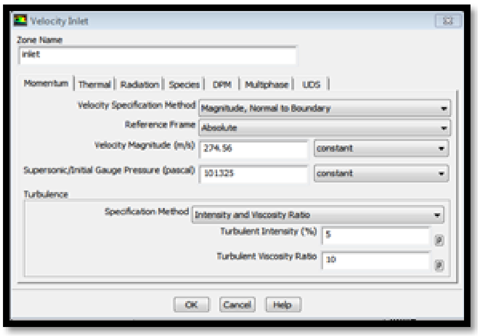
Air Inlet



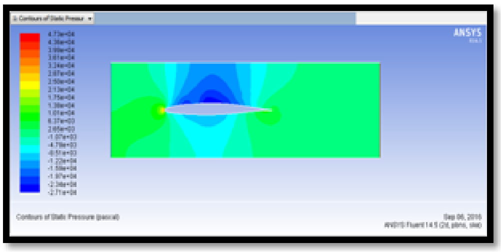
Air Outlet



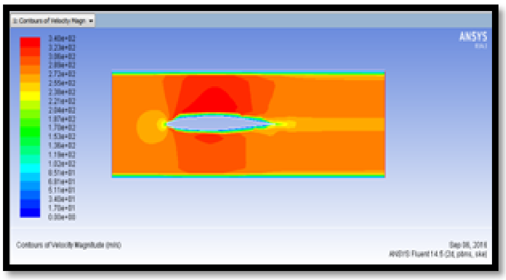
Boundary conditions



Pressure



Velocity



Turbulent kinetic energy

Mass Flow Rate (kg/s)

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inlet 6.8343482
interior-_trm_srf -25.729832
outlet -6.8343563
wall-_trm_srf 0

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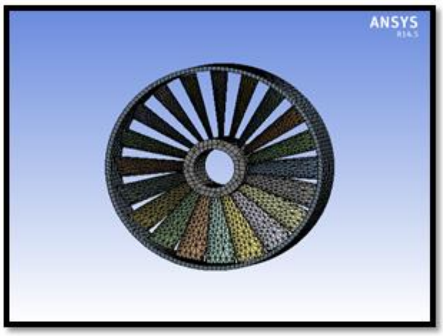
STRUCTURAL ANALYSIS OF AERO ELASTIC OF A TRANSONIC FAN BLADE

Mach number 0.8

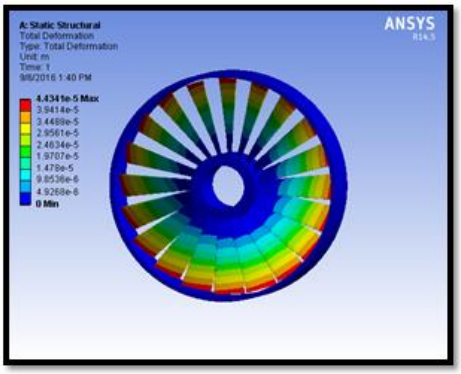
BOUNDARY CONDITIONS – The pressure applied on the blade is engaged from the results of CFD analysis done above and rotational velocity.

Meshed model

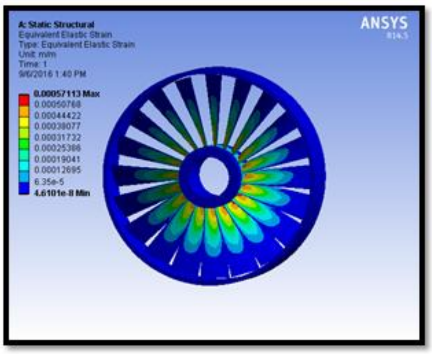


MATERIAL – STAINLESS STEEL

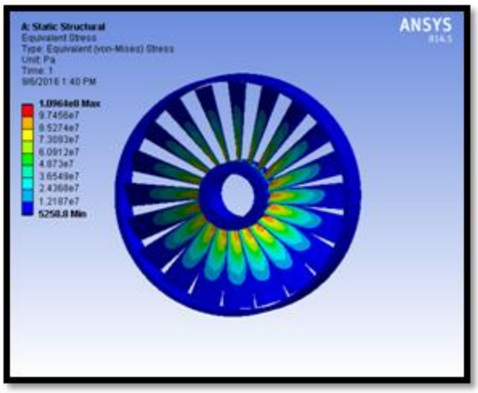
Deformation



Strain



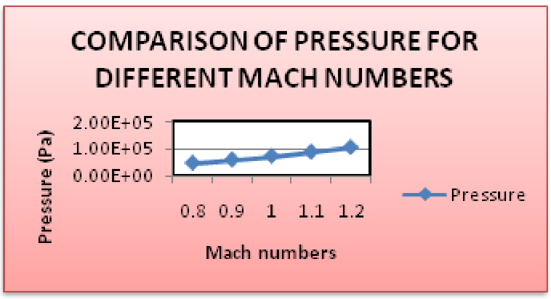
Stress



RESULTS & DISCUSSIONS

CFD ANALYSIS

Mach numbers	Pressure (Pa)	Velocity (m/s)	Turbulent kinetic energy(k)(m^2/s^2)	Mass flow rate (kg/s)
0.8	4.73e+04	3.40e+02	6.42e+02	-8.1062317e-06
0.9	5.97e+04	3.83e+02	7.93e+02	-1.001358e-05
1	7.36e+04	4.26e+02	9.59e+02	5.722e-6
1.1	8.89e+04	4.69e+02	1.14e+03	3.8146973e-06
1.2	1.06e+05	5.11e+02	1.33e+03	2.8610229e-06



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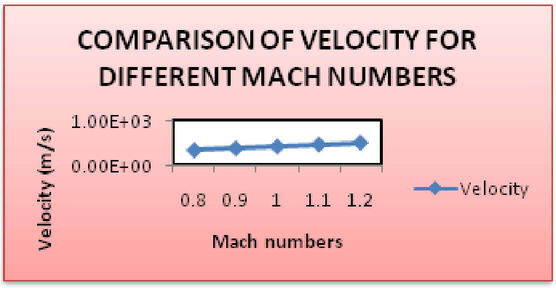
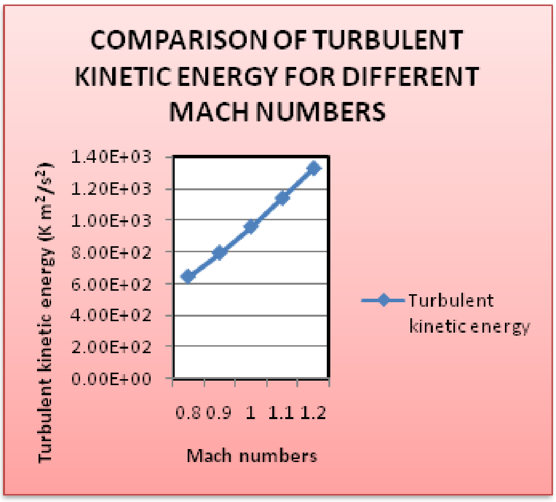
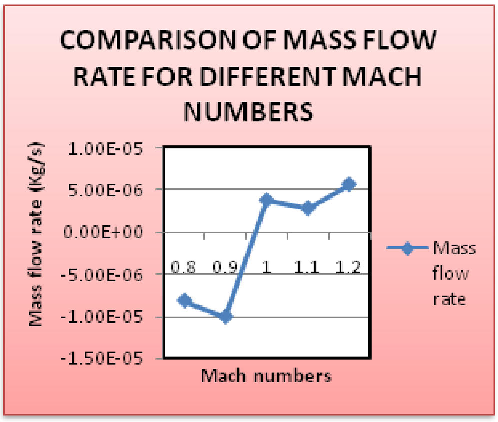
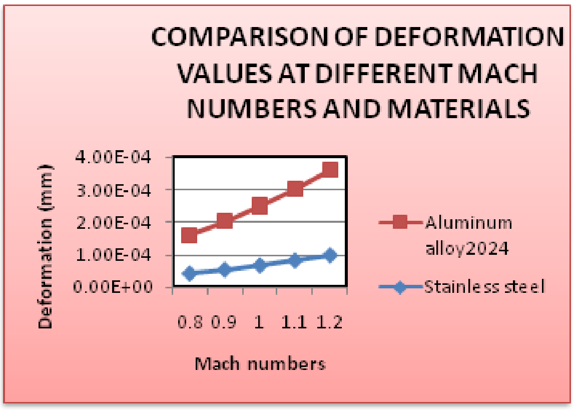






STRUCTURAL ANALYSIS

Mach number	Materials	Deformation (mm)	Strain	Stress (Pa)
0.8	Stainless steel	4.4341e-05	0.00057113	1.0964e8
	Aluminum alloy 2024	0.00011591	0.0014982	1.0883e8
0.9	Stainless steel	5.59e-5	0.00071985	1.3818e8
	Aluminum alloy 2024	0.00014624	0.0018901	1.3729e8
1	Stainless steel	6.8858e-5	0.00088655	1.7019e8
	Aluminum alloy 2024	0.00018023	0.0023293	1.692e8
1.1	Stainless steel	8.312e-5	0.00107	2.0541e8
	Aluminum alloy 2024	0.00021765	0.0028128	2.0432e8
1.2	Stainless steel	9.906e-5	0.0012751	2.4478e8
	Aluminum alloy 2024	0.00025947	0.0033532	2.4357e8



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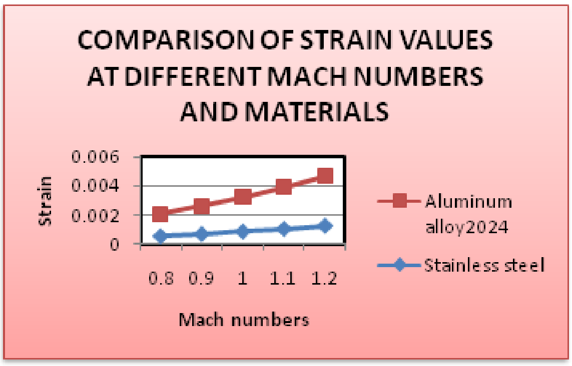

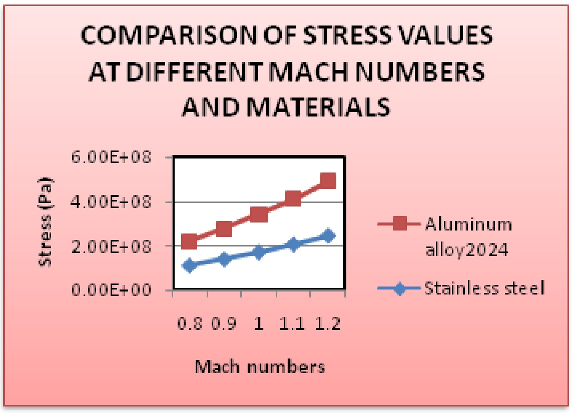

CONCLUSION:

By observing CFD analysis results, the pressure, velocity and turbulent kinetic energy is increasing by increase of Mach number. By increase of these values, the efficiency of the fan increase due to high output values. By observing the static analysis results, the deformation and stress values are increasing for higher Mach number due to high pressures. By comparing between the materials, the stress values are less than the yield stress values for both materials and they more for Aluminum alloy than Steel. But Aluminum alloy can be preferred due to its high strength to weight ratio.

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