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Fluid, Thermal and Static Analysis of Radial Flow Micro Gas Turbine Using CFD

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ABSTRACT

A turbine blade is the person aspect element which makes up the turbine phase of a gasoline turbine. The blades are responsible for extracting electricity from the high temperature, high strain gas produced with the useful resource of the combustor. The turbine blades are regularly the limiting thing of fuel mills. To survive in this tough environment, turbine blades often use exceptional substances like tremendous alloys and masses of amazing methods of cooling, which includes inner air channels, boundary layer cooling, and thermal barrier coatings. In this challenge, a turbine blade is designed and modeled in 3-d modeling software CREO.

The design is modified by using converting the base of the blade to boom the cooling performance. Since the design of turbo machinery is complicated, and performance is immediately associated with fabric performance, material selection is of top importance. In this challenge, substances are considered for turbine blade titanium alloy and nickel alloy.

Optimization is executed via varying the materials Titanium alloy and Super Alloy with the aid of acting coupled field analysis (thermal structural) on the turbine blade for both the designs.

Keywords *- CFD, CFX, Radial Turbine, Micro Gas Turbine, FEA, Thermal.*

1. INTRODUCTION

The contemporary fashion towards miniaturization, portability and extra in popular ubiquitous intelligence, has brought about the improvement of an extensive variety of recent products including laptops, cellular telephones, PDAs, and so on. However, the electricity requirements of such systems have acquired a lot less attention: normally, traditional battery-operated digital systems are used. Nevertheless, the electricity density of most gasoline types remains 100 instances extra than that of the most performing batteries, which makes the usage of a gasoline-primarily based micro power unit thrilling. Such energy devices can be based on a huge range of running concepts, starting from fuel cells and thermo-electric powered gadgets, to combustion engines and gasoline generators. While gas cells are anticipated to provide the highest performance, micro fuel mills are anticipated to offer the very best power density.

A first prototype of a turbine driven through compressed air suggests that speed is the restricting element for each energy and performance. The next step, the improvement of a whole gas turbine, is frequently more difficult, and is not clearly the cutting down of large gasoline generators.

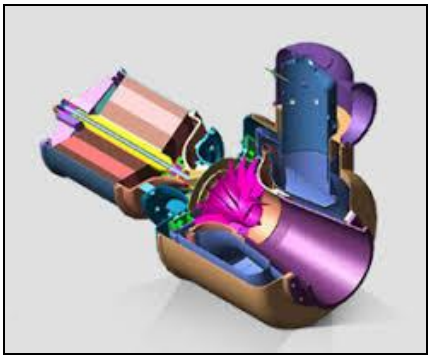

Fig 1: Micro Gas Turbine.

1.1. Micro Gas Turbine

Gas turbines are among the most advanced systems as they combine intense situations in phrases of rotational speed with multiplied gas temperatures (up to 2100 K for army engines). Miniaturisation of this kind of gadget poses amazing technical problems as it results in extremely excessive rotational speeds (e.g. 106 rpm). Moreover, scaling down the device unfavorably influences the waft and combustion method. Fabricating such gadgets calls for new substances to be explored (along with Si3N4 and SiC) and also requires three-dimensional micro manufacturing processes.

The micro gas turbine evolved by way of the Belgian Power MEMS undertaking has a rotor diameter of 20 mm and could produce a strength output of approximately one thousand W. The device essentially consists of a compressor, regenerator, combustion chamber, turbine and electrical generator

In order to accommodate the enormously big extent of each the combustion chamber and the recuperator in a compact manner, an annular design turned into selected for both components. As a result of the adopted layout, the freshest part - the combustion chamber - is enclosed by using the recuperator at the out of doors and through the exhaust diffuser at the interior. This permits to recycle heat losses from the combustion chamber. An exhaust diffuser is delivered to create a sub-ambient strain at the turbine go out, such that more power may be extracted.

To keep away from demagnetization of the magnets, the generator is placed away from the recent elements and the inlet air is aspirated through cooling channels in the generator stator. Generator, compressor and turbine are established on a unmarried shaft for simplicity and reliability.

1.2 Uses of Micro Gas Turbines

Micro Gas Turbines may be used for numerous functions. MGTs most normally are used for strength era process, wherein the strength generated by a MGT is used to force a generator which generates strength and then this excessive frequency strength is transformed into usable 50/60Hz power using a rectifier and inverter meeting. Recently, MGTs have discovered there makes use of in vicinity of dispensed energy supply. MGTs are getting used to strength vehicles also.

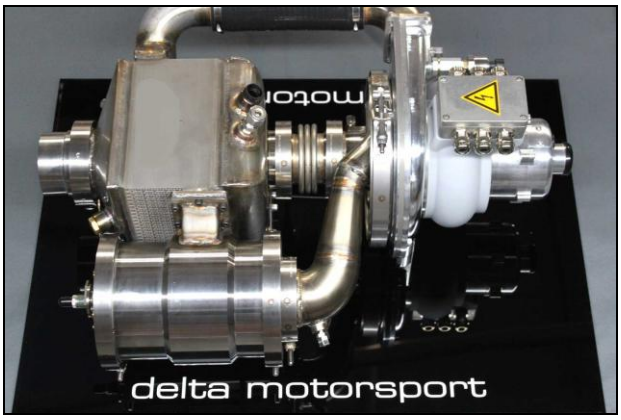

Fig 2: Micro Gas Turbine Used with Automobile Engine.

The businesses like GM, Toyota, Ford, Daimler Benz, and many others. Have invested a whole lot inside the research concerning using MGT in cars, however due to certain components, they by no means commercialized any of the automobiles. But nonetheless, researches are being finished to use the identical for powering motors. In this subject, a number of the hybrid automobiles have also come inside the image which makes use of the gas generators as considered one of its supply.

2. LITERATURE REVIEW

Micro turbine is one of the important additives in a micro gas turbine engine. Micro gasoline turbine engine is a promising approach to provide excessive-density power supply for micro systems. A micro gas turbine engine consists of a radial influx turbine, a centrifugal compressor and a combustor. This thesis specifically offers with the layout elements of a micro turbine. Various journals have been published on designing of diverse styles of micro generators. Exhaustive study has been carried out on these papers and the primary factors were highlighted here. In the paper ―Design, fabrication and characterization of an air-driven micro turbine device‖ by means of X. C. Shan, and Qide Zhang [1],

3. GEOMETRY AND FE MODELLING

3.1 Geometry Details

Computer-aided layout (CAD), additionally called pc -aided layout and drafting (CADD), is using computer technology for the method of format and layout-documentation. Computer Aided Drafting describes the device of drafting with a laptop. CADD software or environments, offer the individual with enter-equipment for the

purpose of streamlining format processes; drafting, documentation, and manufacturing techniques. CADD output is frequently in the shape of virtual documents for print or machining operations. The improvement of CADD-primarily based software is in direct correlation with the strategies it seeks to keep money; enterprise-based software program program (production, manufacturing, and so on.) typically makes use of vector-based (linear) environments whilst image-primarily based totally software program utilizes raster-based totally (pixelated) environments.

CAD environments often involve more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD should deliver facts, in conjunction with substances, procedures, dimensions, and tolerances, in keeping with application-specific conventions.

CAD can be used to format curves and figures in -dimensional (2D) area; or curves, surfaces, and solids in 3-dimensional (three-D) gadgets and is a critical business artwork considerably utilized in masses of programs, such as automobile, shipbuilding, and aerospace industries, business and architectural design, prosthetics, and masses of more. CAD is likewise widely used to supply pc animation for computer graphics in films, advertising and technical manuals. The modern-day-day ubiquity and energy of pc structures method that even perfume bottles and shampoo dispensers are designed the use of techniques amazing with the resource of engineers of the 1960s. Because of its extensive economic significance.

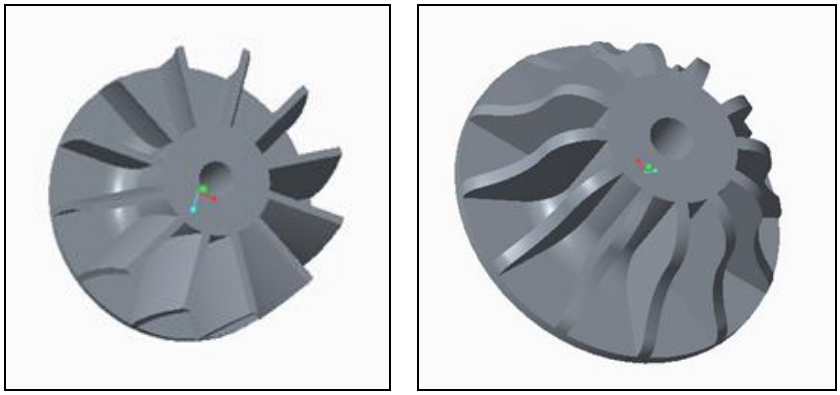

Fig 3: Present and Modified Micro Gas Turbine Model.

3.2 FE Modelling

Finite Element Analysis (FEA) changed into first advanced in 1943 through R. Courant, who utilized the Ritz technique of numerical assessment and minimization of variation calculus to gather approximate solutions to vibration systems. Shortly thereafter, a paper [2] posted in 1956 with the aid of M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Topp established a broader definition of numerical evaluation. The paper focused at the "stiffness and deflection of complicated structures".

ANSYS is general-motive finite detail evaluation (FEA) software program bundle deal. Finite Element Analysis is a numerical technique of deconstructing a complicated gadget into very small portions (of character-precise period) known as factors. The software program implements equations that govern the behavior of these factors and solves the all; growing a entire explanation of ways the machine acts as an entire. These outcomes then may be provided in tabulated or graphical bureaucracy. This kind of assessment is typically used for the format and optimization of a machine a ways too complex to investigate by means of hand. Systems that may work into this class are too complex due to their geometry, scale, or governing equations.

ANSYS is the standard FEA coaching device within the Mechanical Engineering Department at many schools. ANSYS is likewise utilized in Civil and Electrical Engineering, in addition to the Physics and Chemistry departments.

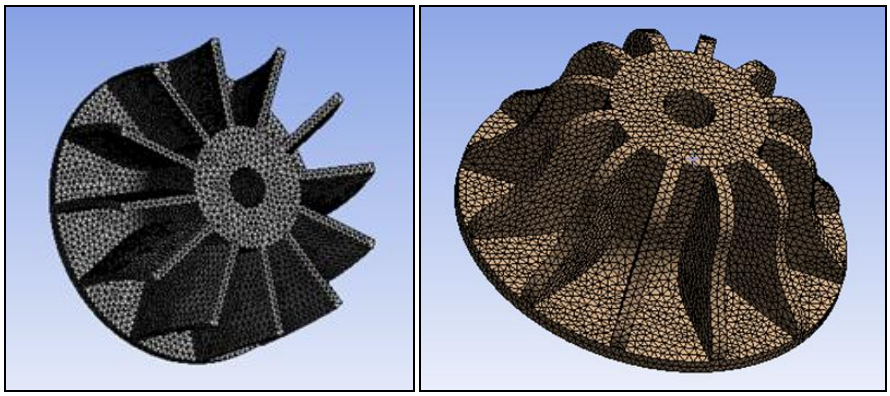

Fig 4: Present and Modified Mathematical Model of Micro Gas Turbine Model.

4. RESULTS AND DISCUSSION

Static analysis of micro gas turbine for both the models shown below foe the best material case titanium alloy turbine. Results compared for the other materials in the table for better understanding of static analysis for all the materials.

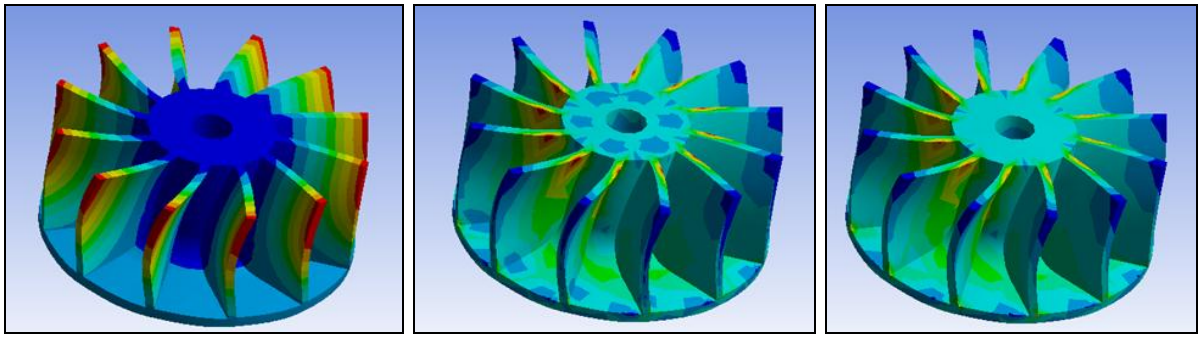

Fig 5: Deformation, Stress and Strain for Present Micro Gas Turbine (Titanium Alloy).

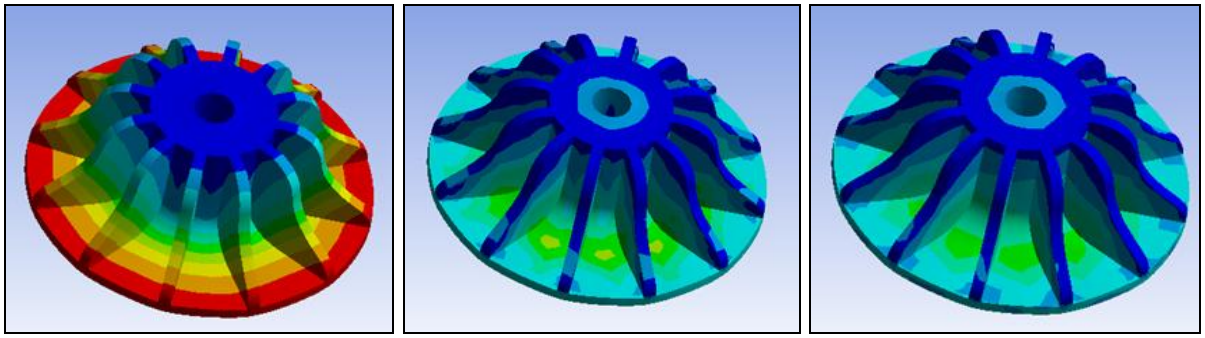

Fig 6: Deformation, Stress and Strain for Modified Micro Gas Turbine (Titanium Alloy).

Thermal analysis of micro gas turbine for both the models shown below for the best material case nickel alloy turbine. Results of thermal analysis compared for the other materials in the table for better understanding of static analysis for all the materials.

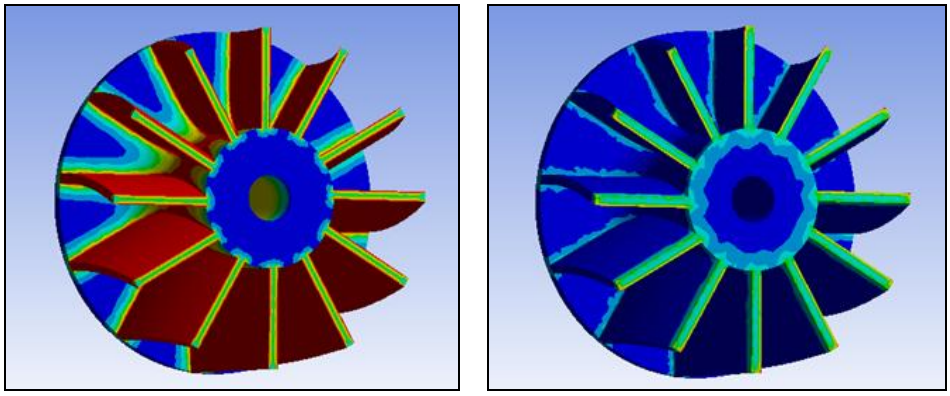

Fig 7: Temperature and Heat Flux for Present Micro Gas Turbine (Nickel Alloy).

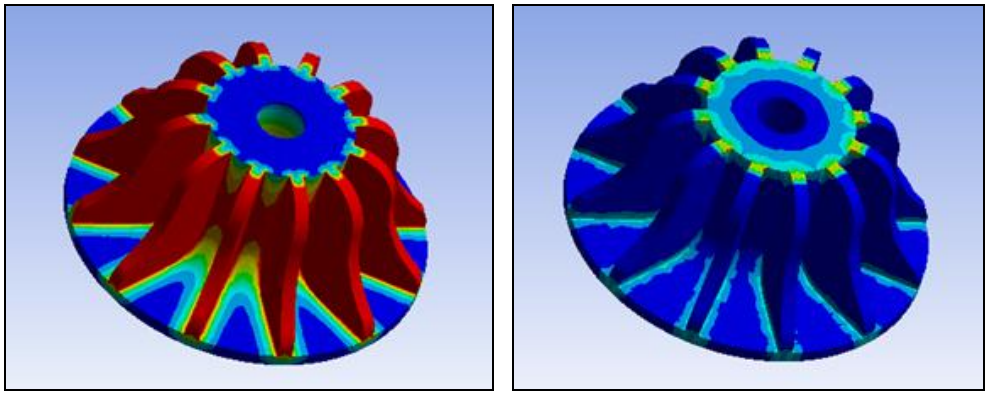

Fig 8: Temperature and Heat Flux for Modified Micro Gas Turbine (Nickel Alloy).

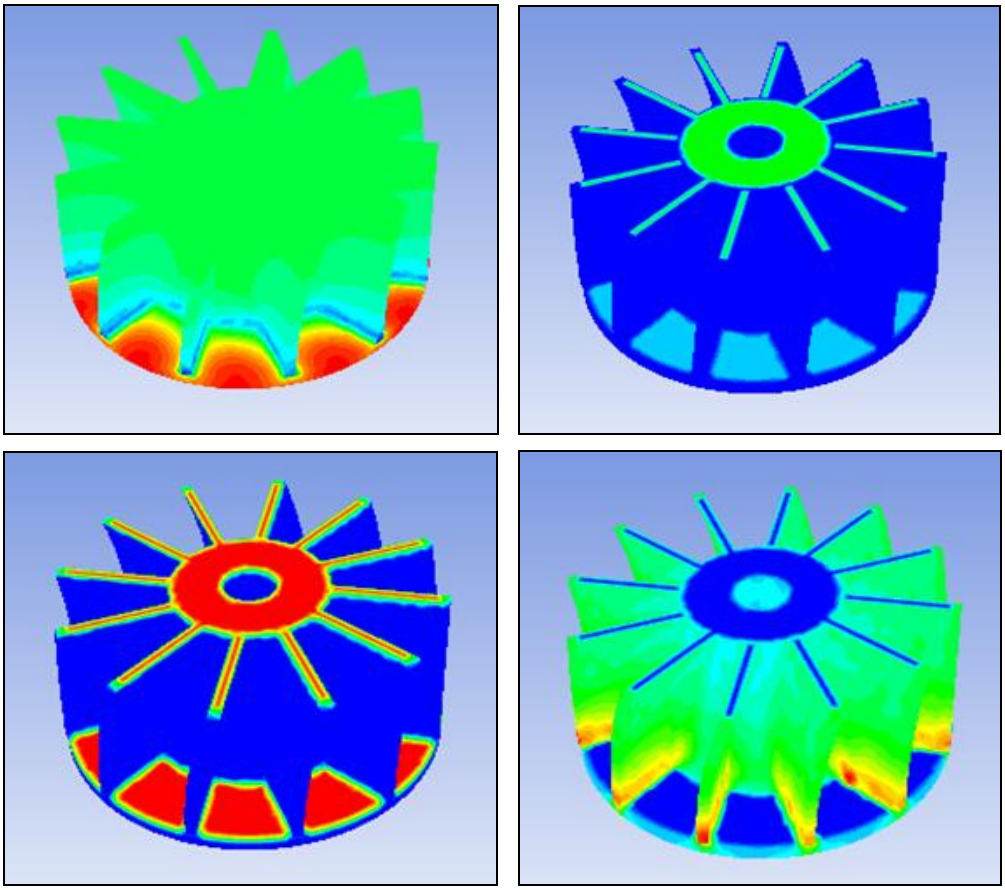

Fig 9: Pressure, Velocity, Temperature and HTC at V= 540 m/s.

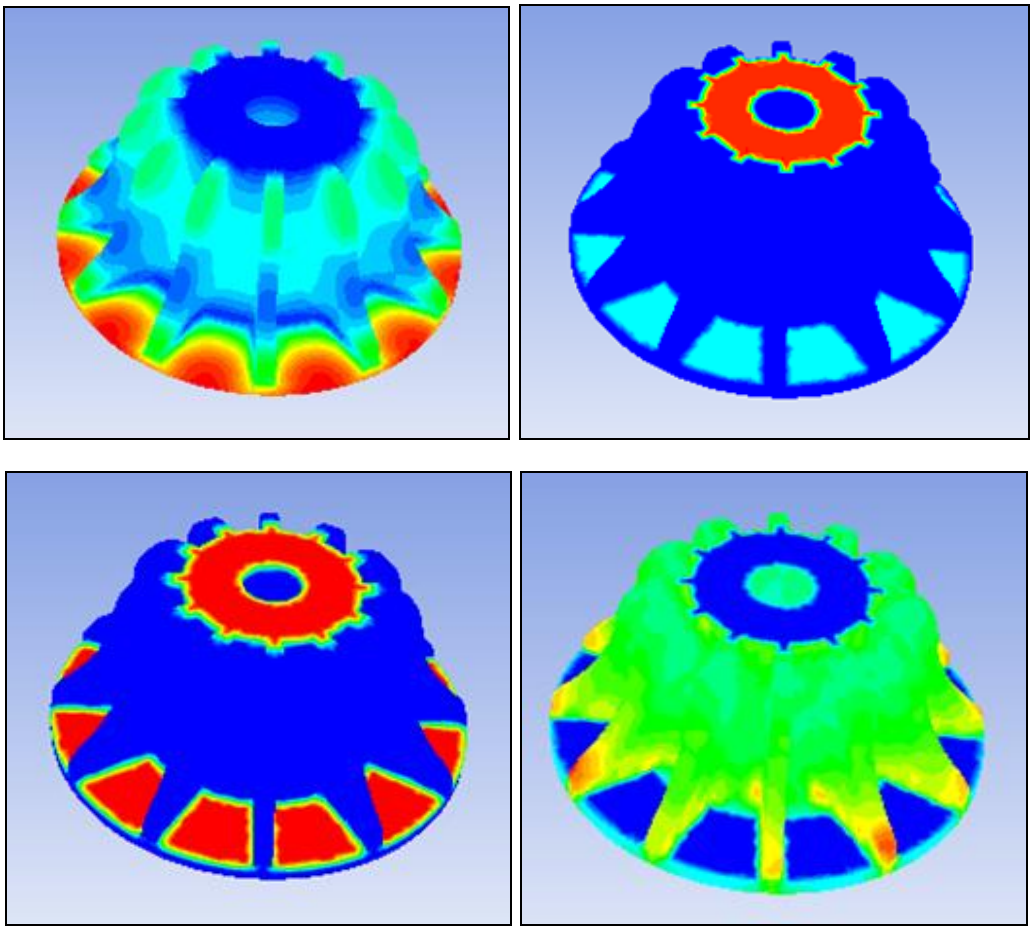

Fig 10: Pressure, Velocity, Temperature and HTC at V= 540 m/s.

CFD analysis is shown in fig 9 & 10 at velocity 0f 540 m/s for present and modified models respectively. Other CFD results are compared in the table-3 for better understanding of CFD results.

Geometry	Material	Temperature (K)		Heat flux
		MIN	MAX	
Present	Steel	302.22	1203.4	18.5
	Titanium	301.22	1203.6	8.966
	Nickel	305.23	1203.4	20.012
Modified	Steel	306.63	1203.5	19.324
	Titanium	173.54	1203.1	9.1194
	Nickel	308.12	1203.5	21.218

Table 1: Thermal Analysis Results.

Geometry	Material	Deformation (mm)	Stress (n/mm^2)	Strain
Present	Steel	0.054949	43.467	0.00023628
	Titanium	0.066426	25.629	0.0002849
	Nickel	0.065704	49.326	0.00028375
Modified	Steel	0.010477	34118	0.0002035
	Titanium	0.011804	18.684	0.000238
	Nickel	0.012666	39.117	0.00024479

Table 2: Static Analysis Results.

Geometry	Inlet velocity (m/s)	Pressure (Pa)	V (m/s)	T (K)	HTC	Mass flow rate	Heat transfer rate
Present	320	1.74E+05	8.32E+02	1.20E+03	2.42E+03	0.004	93142
	420	1.76E+05	1.25E+03	1.20E+03	3.21E+03	0.0055	127789
	540	3.07E+05	1.67E+03	1.20E+03	3.93E+03	0.0071	160419
Modified	320	2.09E+05	1.10E+03	1.20E+03	2.66E+03	0.002	123244
	420	4.10E+05	1.54E+03	1.20E+03	3.46E+03	0.0034	160926
	540	6.76E+05	1.98E+03	1.20E+03	4.17E+03	0.0038	175867

Table 3: CFD Analysis Results.

5. CONCLUSION

In this project, a micro gas turbine is designed and modeled in 3D modeling software CREO. The design is present and modified models by changing blade to increase the cooling efficiency and strength. Since the design of turbo machinery is complex, and efficiency is directly related to material performance, material selection is of prime importance.

In this project, three materials are considered for turbine blade chromium steel, titanium alloy and nickel alloy. Optimization is done by varying the materials by performing coupled field analysis (Thermal + Structural + Fluid) on the micro gas turbine for both the designs.

By observing CFD analysis results, the heat transfer value more for modified model compared to original model at velocity (540 m/s). With increasing blade velocity increases also pressure, velocity and heat transfer rates.

By observing Thermal analysis results, the heat flux value more for modified model with nickel alloy compared to other materials and from the static analysis results, the stress value less for modified model with titanium alloy compared to other materials. So we can conclude that, the modified model is better.

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