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ANALYSIS OF A COMBUSTION CHAMBER USING DIFFERENT PROFILED HOLE RIBS FOR A SMALL SCALE GAS TURBINE

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ABSTRACT

Micro-gas turbine (MGT) usually produces between 25 and 500 kW of electrical power, it has minimal maintenance and operational cost, high power density and low emission. An important factor that attracts researchers to develop MGT's especially for renewable energy fuel types is that it can be operated with various kinds of fuels. Micro-gas turbine in recent times is given attention for decentralized generation of renewable energy. There has been a renewed interest on the MGT development and deployment on small scale distributed cogeneration (DG) and poly-generation concepts. Micro-gas turbines (MGT) are small-scale independent and reliable distributed generation systems that offer potential for saving energy and reducing carbon monoxide (CO) emissions. They are expected to play a vital role in future energy supplies for remote locations with or without grid connections. In this paper, a design and development of a combustion chamber for micro-gas turbine was performed by CATIA and computational fluid dynamics (CFD) ANSYS-FLUENT simulation software. Different chamber geometries were used to simulate with species transport and non-premixed combustion models to determine the optimum chamber design. So different profile hole ribs are developed to get the better heat transfer rate and to achieve higher life. So different materials are used here and analyzed to obtain the best output for a stable combustion with CO emission of turbine having inlet temperature below 900 °C.

INTRODUCTION

A combustor may be a component or area of a turbine, ramjet, or scramjet engine where combustion takes place. It is also referred to as burner, combustion chamber or flame holder. In a turbine engine, the combustor or combustion chamber is fed high air by the compression system. The combustor then heats this air at constant pressure. After heating, air passes from the combustor through the nozzle guide vanes to the turbine.

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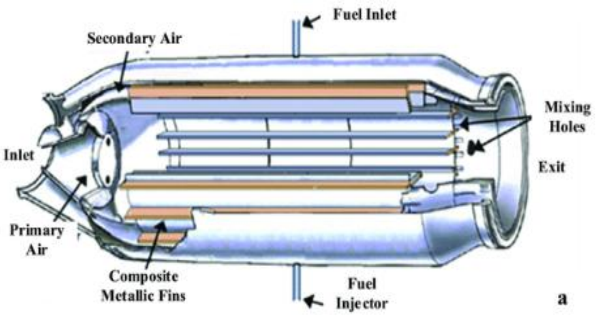
In the case of a ramjet or scramjet engines, the air is directly fed to the nozzle.

A combustor must contain and maintain stable combustion despite very high air flow rates. To do so combustors are carefully designed to first mix and ignite the air and fuel, then mix in additional air to finish the combustion process. Early turbine engines used one chamber referred to as a can type combustor. Today three main configurations exist: can, annular and cannular (also mentioned as can-annular tubo-annular). Afterburners are often considered another sort of combustor. Combustors play an important role in determining many of an engine's operating characteristics, like fuel efficiency, levels of emissions and transient response (the response to changing conditions like fuel flow and air speed).



TYPES AND CLASSIFICATIONS

1. Can
2. Cannular
3. Annular
4. Double annular

Can

Can combustors are self-contained cylindrical combustion chambers. Each "can" has its own fuel injector, igniter, liner, and casing. The primary air from the compressor is guided into each individual can, where it's decelerated, mixed with fuel, then ignited. The secondary air also comes from the compressor, where it's fed outside of the liner (inside of which is where the combustion is taking place). The secondary air is then fed, usually through slits within the liner, into the combustion zone to relax the liner via thin film cooling. In most applications, multiple cans are arranged round the central axis of the engine, and their shared exhaust is fed to the turbine(s). Can type combustors were most generally utilized in early turbine engines, due to their simple design and testing (one can test one can, instead of have to test the whole system). Can type combustors are easy to take care of , as only one can must be removed, instead of the entire combustion section. Most modern turbine engines (particularly for aircraft applications) don't use can combustors, as they often weigh quite alternatives. Additionally, the pressure drop across the can is usually above other combustors (on the order of 7%). Most modern engines that use can combustors are turboshafts featuring centrifugal compressors.

Cannular

the next sort of combustor is that the cannular combustor; the term may be a portmanteau of "can annular". Like the can type combustor, can annular combustors have discrete combustion zones contained in separate liners with their own fuel injectors. Unlike the can combustor, all the combustion zones share a typical ring (annulus) casing. Each combustion zone not has got to function a pressure vessel. The combustion zones also can "communicate" with one another via liner holes or connecting tubes that allow some air to flow circumferentially. The exit be due the cannular combustor generally features a more uniform temperature profile, which is best for the turbine section. It also eliminates the necessity for every chamber to possess its own igniter. Once the hearth is lit in one or two cans, it can easily spread to and ignite the others. This type of combustor is additionally lighter than the can type, and features a lower pressure drop (on the order of 6%). However, a cannular combustor are often harder to take care of than a can combustor. Examples of gas turbine engines utilizing a cannular combustor include the General Electric J79 turbojet and the Pratt & Whitney JT8D and Rolls-Royce Tay turbofans.

Annular

the final, and most ordinarily used sort of combustor is that the fully annular combustor. Annular combustors do away with the separate combustion zones and easily have endless liner and casing during a ring (the annulus). There are many advantages to annular combustors, including more uniform combustion, shorter size (therefore lighter), and fewer area. Additionally, annular combustors tend to possess very uniform exit temperatures. They even have rock bottom pressure drop of the three designs (on the order of 5%). The annular design is additionally simpler, although testing generally requires a full size test rig. An engine that uses an annular combustor is that the CFM International CFM56. Almost all of the fashionable turbine engines use annular combustors; likewise, most combustor research and development focuses on improving this type.

Double annular combustor

One variation on the quality annular combustor is that the double annular combustor (DAC). Like an annular combustor, the DAC may be a continuous ring without separate combustion zones round the radius. The difference is that the combustor has two combustion zones round the ring; a pilot zone and a main zone. The pilot zone acts like that of one annular combustor, and is that the only zone operating at low power levels. At high power levels, the foremost zone is used also, increasing air and mass flow through the combustor. GE's implementation of this sort of combustor focuses on reducing NOx and CO2 emissions. A good diagram of a DAC is out there from Purdue. Extending an equivalent principles because the double annular combustor, triple annular and "multiple annular" combustors are proposed and even patented.

LITERATURE SURVEY

Kalapala Prasad [1] et.all investigated the gas turbine blade aiming for numerical analysis of the twisted airfoil. The natural frequency of the gas turbine blade is evaluated by adopting Hozler's Method. The author analysed the shape of the blade and twisted it to make it more efficient. The natural frequency obtained through Hozler's Technique is analysed so as to improve the efficiency of the turbine.

Tim J Carter [2] et.all described about the failures of gas turbine blades. Most of the failures were detected and the appropriate action taken to prevent the failures. The causes we identified as exposure to high temperature causes the blade to undergo creep. Also the properties of combusted gas cause corrosion in the blades. The continuous load on the turbine blade causes fatigue failure.

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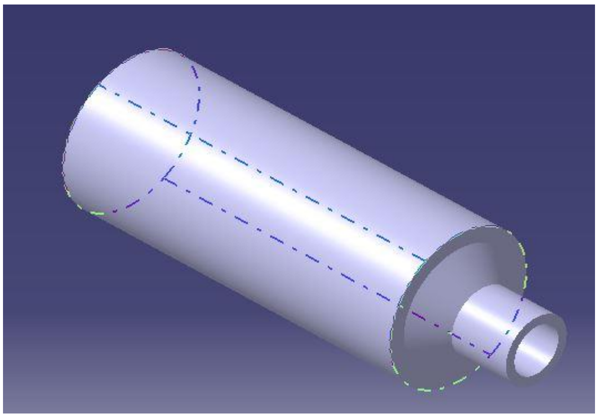
X.Q. Cao [3] et. All investigate the properties of barrier coating for the ceramic materials used in the gas turbine engines. The Ceramic materials used for coating have increased the life of blade by protecting it from oxidation, corrosion and wear. Here the top ceramic coating which protects from the heat and acts as the thermal insulation .

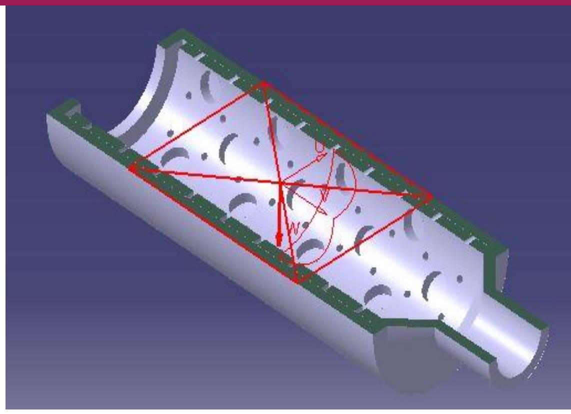
Teju [4] et.al investigated the design and analysis of gas turbine blade. The turbine blades were designed with two different material named Inconel 718 and titanium T-6. Thermal analysis were carried out to investigate the temperature flow which develops due to thermal loading. A structural analysis were carried out to investigate the Shear stress and displacement.

C dhatchanamoorthy[5]et.al analyzed the gas turbine combustion chamber and improving combustion efficiency by using ceramic material coating. Here ceramic coated combustion chamber produced more thrust at the same time combustion chamber life also increased.

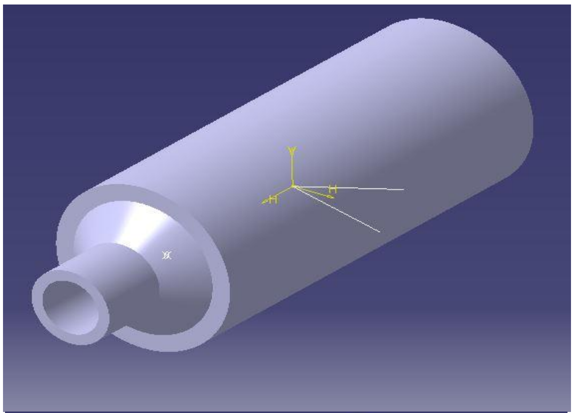
DESIGN

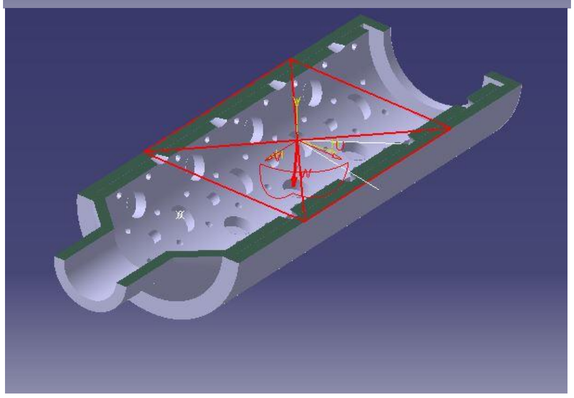
ORIGINAL MODEL



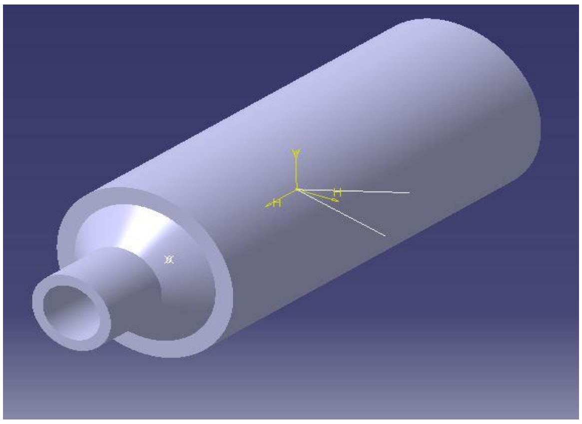


MODIFIED MODEL 1





MODIFIED MODEL 2



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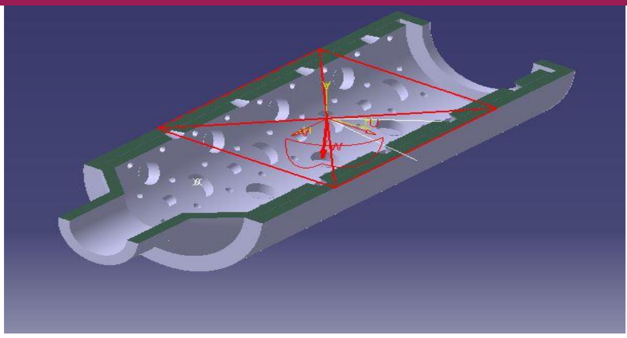
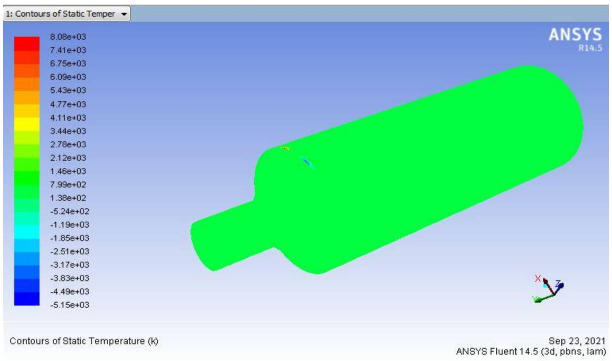


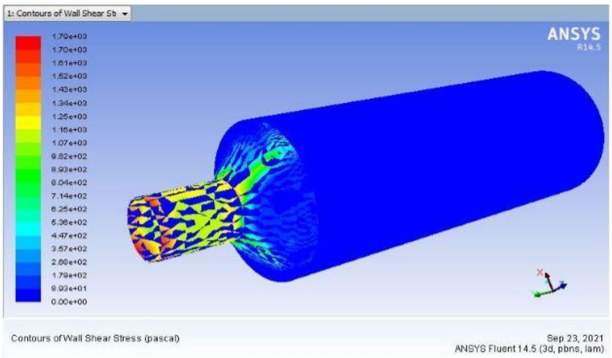
ORIGINAL MODEL

CFD ANALYSIS OF A GAS TURBINE COMBUSTION CHAMBER

TEMPERATURE



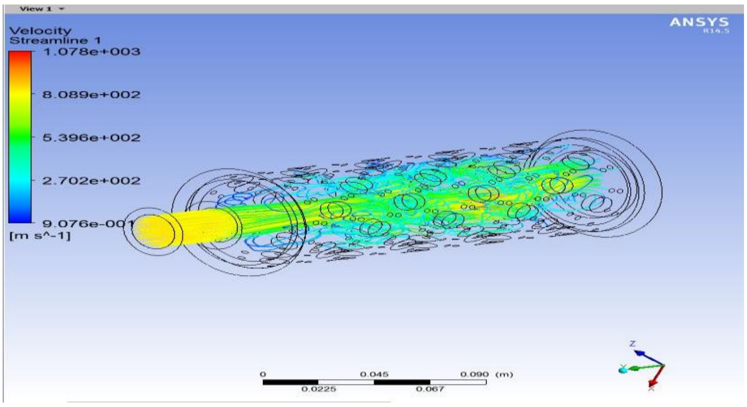
SHEAR STRESS



MASS FLOW RATE

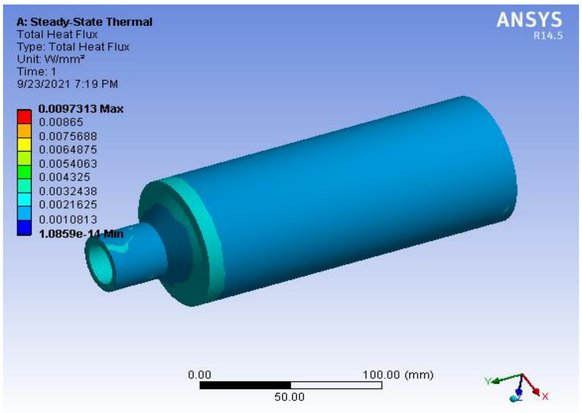
Mass Flow Rate	(kg/s)
inlet	0.42311296
outlet	-0.41144115
Net	0.011671811

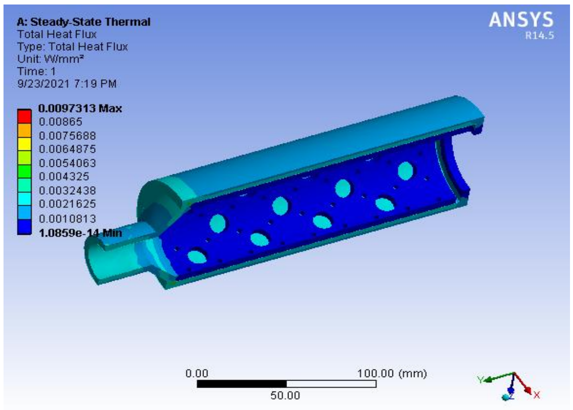
VELOCITY



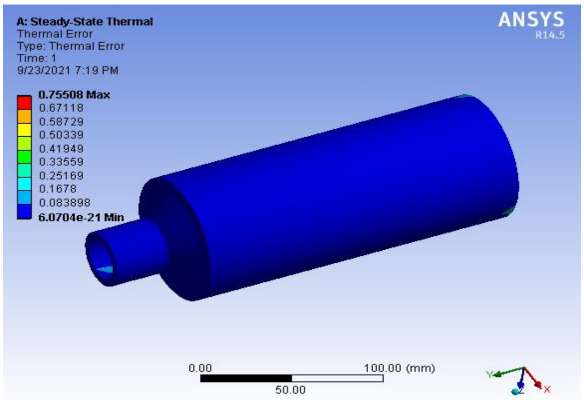
THERMAL ANALYSIS OF A GAS TURBINE COMBUSTION CHAMBER BY USING AL 2024

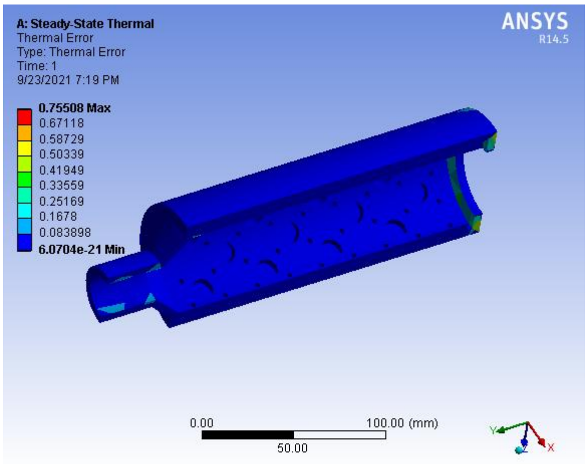
HEAT FLUX





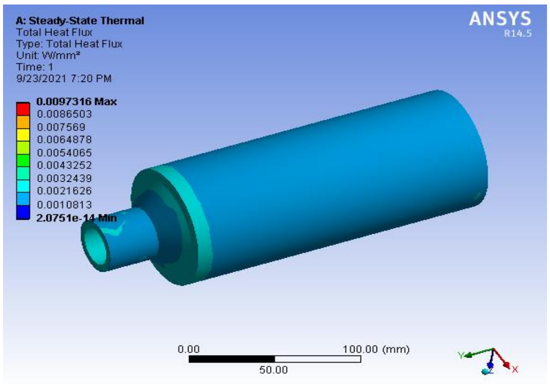
THERMAL ERROR

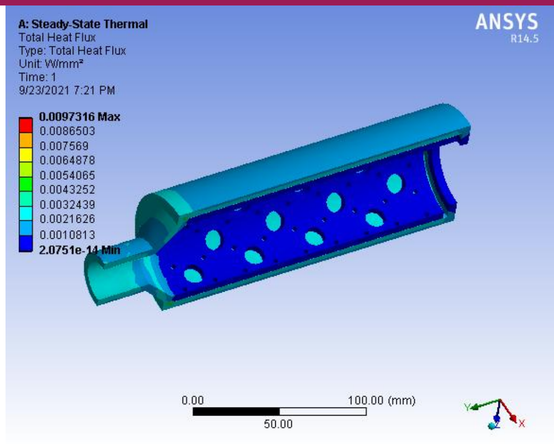




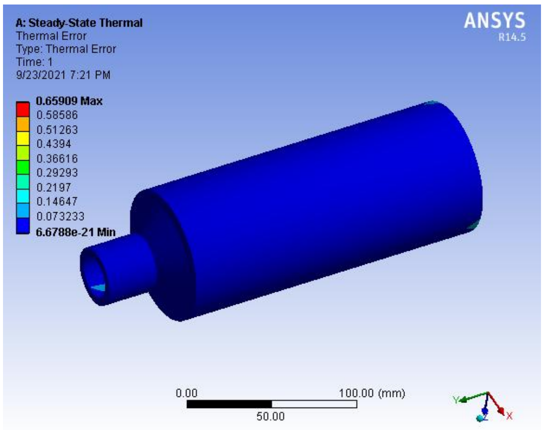
THERMAL ANALYSIS OF A GAS TURBINE COMBUSTION CHAMBER BY USING AL 7475

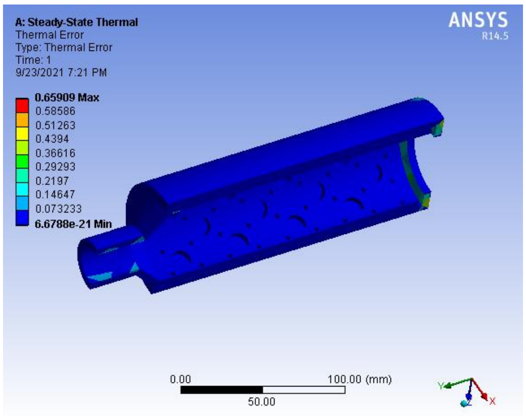
HEAT FLUX





THERMAL ERROR





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TABULAR RESULTS

CFD ANALYSIS

	ORIGINAL	MODIFIED 1	MODIFIED 2
Static pressure	6.12E+04	1.50E+08	4.23E+08
Static temperature	8.08E+03	6.24E+03	7.07E+02
Wall shear stress	1.79E+03	7.19E+03	1.40E+05
Heat transfer coefficient	1.16E+03	3.21E+02	1.07E+03
Mass flow rate	0.011671811	0.76546478	0.23348999
Heat transfer rate	14864.375	233670	96044
Velocity	1.078E+003	1.661E+005	1.727E+005

THERMAL ANALYSIS

	Temperature (^0C)	Heat flux (W/mm^2)	Directional heat flux (W/mm^2)	Thermal error
Original Al 2024	433.85	0.0097313	0.0053038	0.75508
Original Al 7475	433.85	0.0097316	0.005304	0.65909
Modified model 1 Al 2024	433.85	0.01321	0.0056944	0.48796
Modified model 1 Al 7475	433.85	0.01321	0.0056946	0.42594
Modified model 2 Al 2024	433.85	0.012634	0.007467	0.75657
Modified model 2 Al 7475	433.85	0.012634	0.0074673	0.66041

GRAPHS

CFD ANALYSIS

Chart of static temperature

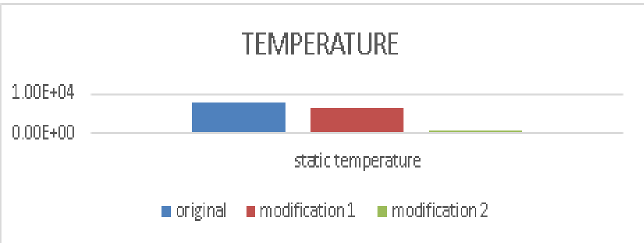


Chart of Wall Shear stress

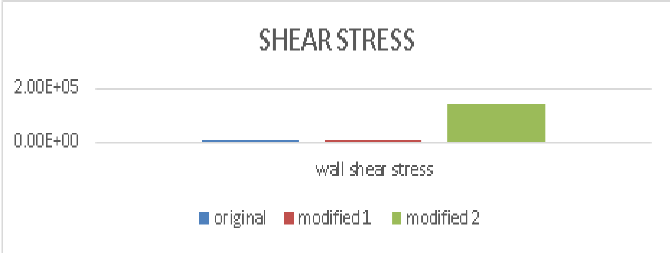


Chart of mass flow rate

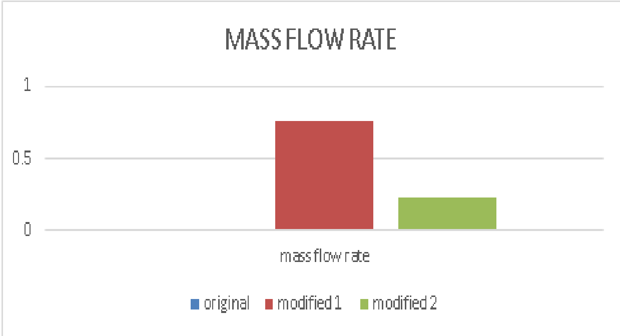
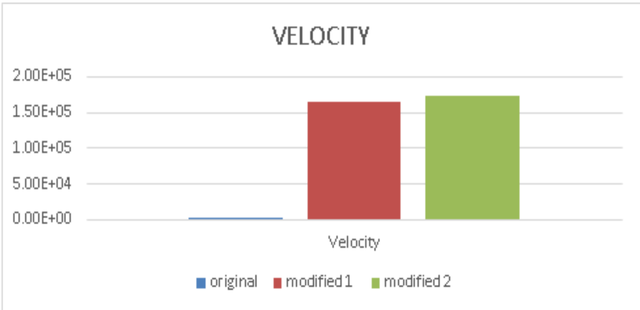


Chart of Velocity



THERMAL ANALYSIS

Chart of heat flux

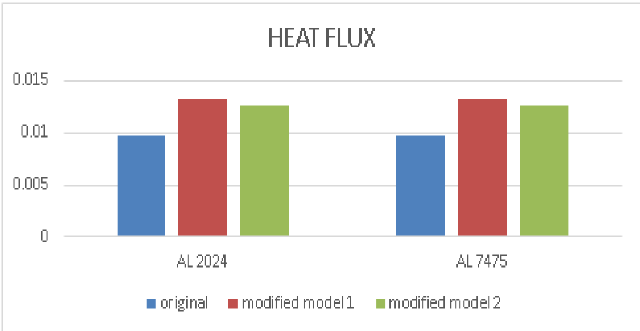


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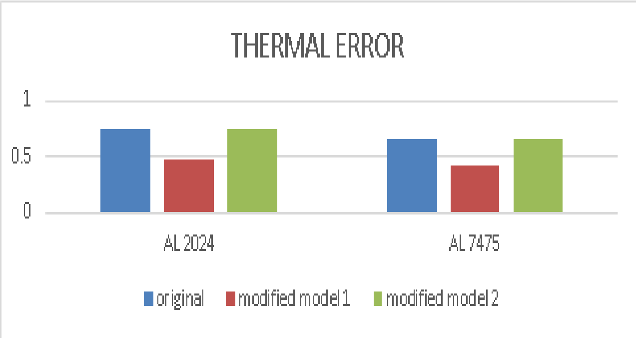
Chart of thermal error



CONCLUSION

In this thesis we are going to design the combustion chamber of a gas turbine using Catia software. As here the utilization of fuel will be high the temperature will be high and even the heat transfer should be high enough to obtain the better life, so here the design procedure of combustion chamber and the working of the chamber is explained clearly, with the CFD simulation is done on the model to verify the heat transfer rate using the producer gas as fluid. As per the output, some design procedures are changed and a new model is been developed to obtain the better heat transfer rate than the existing one. Here even the chamber is verified using at utmost temperature to get the best output. Even thermal analysis is carried out to find the best suited material; here we are going to use aluminum 2024 and 7475 materials to verify the best suited material.

So as if we verify the results obtained in the CFD analysis, we can observe that the temperature is less for the modified model 2, but there is a slight increase in the stress levels. As if we verify the complete results in terms of velocity, heat transfer rate, mass flow of the producer gas and stress levels, here the modified model 1 has obtained the better outputs and can achieve the better efficiency.

But as if we compare the results obtained for the thermal analysis, here the heat evaporation is more for the modified model 1, and even the thermal error is also very less for the modified model 1 when compared with the other models. As if we verify the materials used here Al 2024 and Al 7475, both the materials have obtained the better results. But only a difference obtained at the thermal error, as per this the Al 7475 is suited with the modified model 1 to obtain the better outputs.

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