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Design and Development of Catalytic Converter for Reduction of Pollution by Using Transient and CFD Analysis

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ABSTRACT

The use of fossil fuels in automobiles mainly HC, CO and NOX which produce harmful green house gases. The main objective of catalytic converter is to reduce and control effect of harmful pollutants by converting toxic CO and NOX to non toxic CO2and H2O. CFD analysis is done in the present study of catalytic converter by taking three different materials for the make of catalytic converter such as stainless steel, Grey cast iron and aluminum at the time by varying different fluids such as methane, ethane and nitrogen at varying speeds of 2000 and2500R.P.M.

KEYWORDS: *ANSYS, CATIA V5 R21, green house gases, pollutants, catalytic converter, varying speeds*

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INTRODUCTION

A catalytic converter is a fumes emanation control gadget that diminishes harmful gases and poisons in fumes gas from an inside burning motor into less-poisonous toxins by catalyzing a redox response (an oxidation and a decrease response). Exhaust systems are normally utilized with inside ignition motors powered by either fuel or diesel—including lean-consume motors just as lamp oil warmers and ovens. The primary boundless presentation of exhaust systems was in the United States car market. To agree to the U.S. Natural Protection Agency's stricter guideline of fumes emanations, most fuel controlled vehicles beginning with the 1975 model year must be outfitted with exhaust systems. These "two-way" converters consolidate oxygen with carbon monoxide (CO) and unburned hydrocarbons (C2H2) to deliver carbon dioxide (CO2) and water (H2O). In 1981, two-way exhaust systems were delivered outdated by "three-way" converters that likewise lessen oxides of nitrogen (NOx) nonetheless, two-way converters are as yet utilized for lean-consume motors. This is on the grounds that three-way-converters require either rich or stoichiometric ignition to effectively diminishNOx. Albeit exhaust systems are most regularly applied to fumes frameworks in vehicles, they are additionally utilized on electrical generators, forklifts, mining gear, trucks, transports, trains, and cruisers. They are likewise utilized on some wood ovens to control discharges. This is for the most part because of government guideline, either through direct ecological guideline or through wellbeing and security guidelines.

Figure 1 A three-way catalytic converter

The emissions of a vehicle engine

Were first planned in France toward the finish of the nineteenth century, when a couple thousand "oil vehicles" were on the streets; it was comprised of a latent material covered with platinum, iridium, and palladium, fixed into a twofold metallic chamber. A couple of many years after the fact, an exhaust system was licensed by Eugene Houdry, a French mechanical specialist and master in reactant oil refining, who moved to the United States in 1930. At the point when the aftereffects of early investigations of brown haze in Los Angeles were distributed, Houdry got worried about the function of smokestack fumes and vehicle exhaust in air contamination and established an organization called Oxy-Catalyst. Houdry originally created exhaust systems for smokestacks called "felines" for short, and later created exhaust systems for distribution center forklifts that pre-owned second rate, unleaded fuel. During the 1950s, he started exploration to create exhaust systems for gas motors utilized on vehicles. From the synthetic perspective, an impetus is any substance ready to quicken a compound response while keeping up its own personal structure. On account of cars, Converter where a practically complete debasement of fumes smoke can be accomplished by synergist responses over a hyperactive zone made of platinum and rhodium. Notwithstanding its humble volume, the dynamic surface region inside an exhaust system would cover two football fields Inside the engine, a cylinder pushes lingering hot gases from the burning chamber to the fumes valve, and when these gases go through the dynamic territories inside the earthenware cells of the converter, two inverse compound cycles happen all the while: an oxidation response which changes over hydrocarbons and carbon monoxide into carbon dioxide and water; and a decrease response of nitrogen oxides to create unadulterated nitrogen. Carbon monoxide is a toxic substance for any air-breathing creature. The catalytic converter systems As the inward ignition motor uses the fumes stroke to remove the' spent' gases by means of the fumes System, the hurtful emanations are gone through an uncommon suppressor type looking gadget called an exhaust system. After the discharges have gone through the Converter they are gone through their s of the fumes framework in the ordinary way lastly to environment. The exhaust systems object is to lessen the first unsafe outflows to unimportant levels by methods for impetus controlled synthetic responses. Inside the structure of the exhaust system is a structure using an impetus.

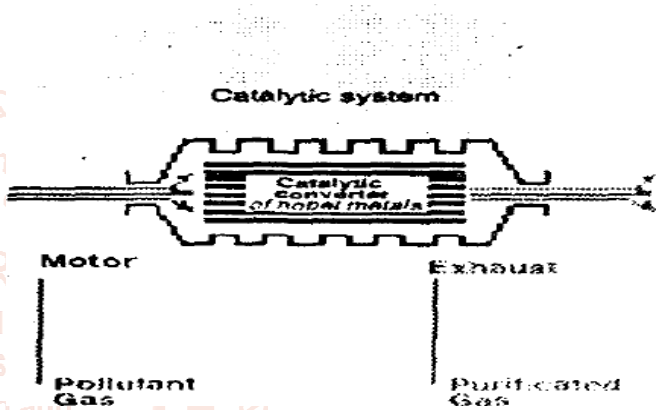

Figure 2.The catalytic converter systems

Catalytic conversion is a three stage process

1. The ReductionCatalyst: This stage comprises of diminishing the emanations of nitrogen oxides by utilizing platinum and rhodium.
2. The OxidationCatalyst: The second phase of the cycle diminishes the unburned hydrocarbons and carbon monoxide by consuming them over a platinum and palladium impetus.
3. The ControlSystem: The control framework essentially screens the fumes stream and takes this data to control the fuel infusion framework. To do this, the exhaust system is outfitted with an oxygen sensor that tells the motor's PC how muchoxygen is in the fumes. This permits the motor's PC to ensurethatthere is sufficient oxygen in the fumes to permit the oxidization impetus to consume the unburned hydrocarbons andCO.

Components of the catalytic converter

There are three primary segments of the Catalytic Converter:

The Monolith (otherwise called the substrate), a fired or metal structure built like a honeycomb, through which fumes gases pass. Wash coat, permeable fired wipe like coatings applied in a dainty layer to the stone monument that increases the surface region to that of

around two football pitches, over which the reactant metals can bekept. The Catalyst, typically comprising of a combination of Platinum and Rhodium in spite of the fact that Palladium is additionally utilized They complete the synthetic responses that purge the fumes.

The catalytic converter operates under the following conditions

Working temperature

The impetus begins working once the stone monument has achieved a temperature of 250-270°C, the temperature (usually known as light-off) which a vehicle will ordinarily reach from cold beginning inside a couple of moments. Under typical working conditions the impetus keeps up a temperature of between 400-600°C. To work most viably, an exhaust system needs to arrive at an ideal temperature. It may not arrive at this in a short excursion. Devises to pre-warm the impetus are being created which improve the general presentation of exhaust systems.

Reactions in a Catalytic Converter

It isn't decisively seen how platinum and rhodium function as impetuses however actually, the exhaust systems activity includes two sorts of responses: - Oxidation Reaction. - Reduction Reaction. Oxidation Reaction: In a Catalytic Converter unburned hydrocarbons are Oxidized to water and carbon dioxide. Decrease Reaction: nitrogen oxides are diminished once more into nitrogen, the significant part of air. The impetus in this chamber makes this conceivable. The converter utilizes two distinct kinds of impetuses, a decrease impetus and an oxidation impetus. The Catalyst, typically comprising of a combination of Platinum and Rhodium in spite of the fact that Palladium is additionally utilized They complete the synthetic responses that purge the fumes.

Amount of impetuses utilized

Platinum or Palladium quicken the oxidation of hydrocarbons and carbon monoxide, while Rhodium decreases the oxides of nitrogen when in doubt there are just between 1-2 grams of valuable metals in each exhaust system The thought is to make a structure that uncovered the most extreme. surface region of impetus to the fumes stream, while additionally limiting the measure of impetus required (they are extravagant).

The catalytic converters type

There are three basic types of automotive catalytic converters

-Two-Way

-Three-Way

and

- Three-Way + Air.

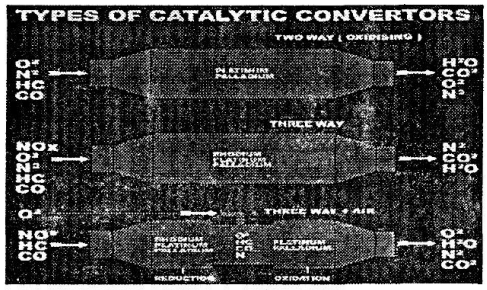

Figure 3 Basic types of automotive catalytic converters

Each type utilizes a somewhat unique strategy and science to decrease the destructive components in exhaust discharges. Early model converters utilized a palletized impetus, yet most modem converters are currently planned with a free streaming honeycomb fired impetus. The sort of converter needed on a specific vehicle differs with model year, motor size and vehicle weight. A few vehicles even utilize more than one sort of converter or a pre converter to fulfill discharge decrease guidelines.

Two-Way Oxidation Converter

A Two-Way converter, utilized on vehicles between 1975 - 1980, oxidizes unburned hurtful hydrocarbons and carbon monoxide into water and carbon dioxide.

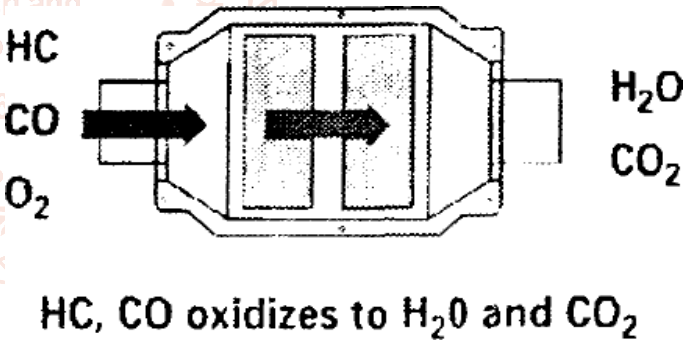

Figure 4 Two-Way Oxidation Converter

METHODOLOGY

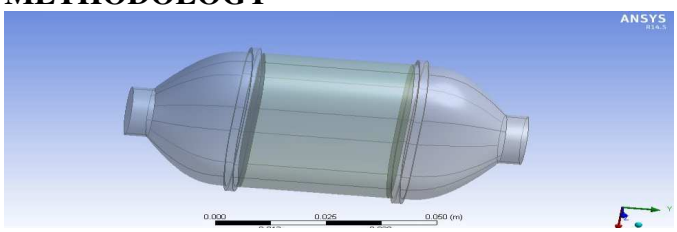

Figure 5 Fluid: Nitrogen At engine speed-2000 RPM

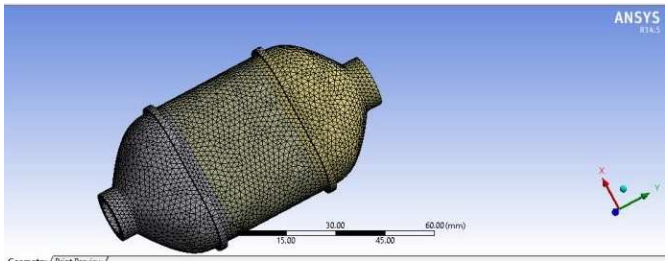

Figure 6 Meshing

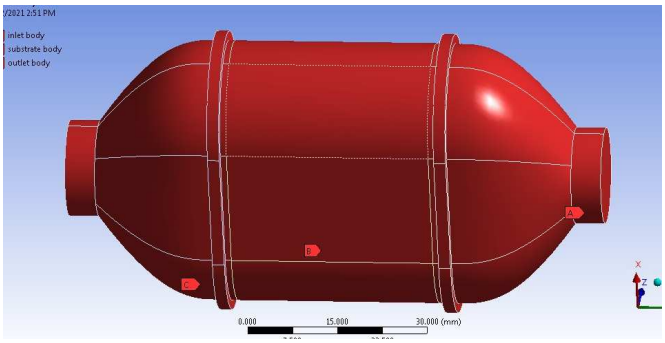

Figure 7 Boundaries for inlet and outlet

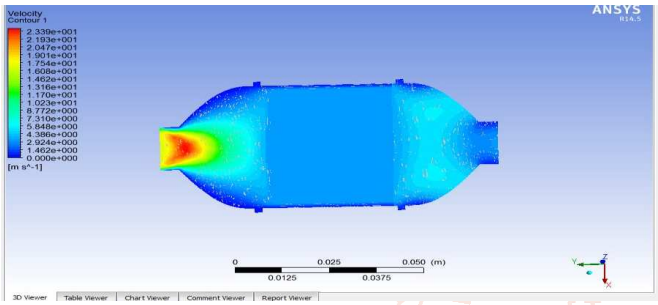

Figure 8 Velocity at 2000rpm for nitrogen

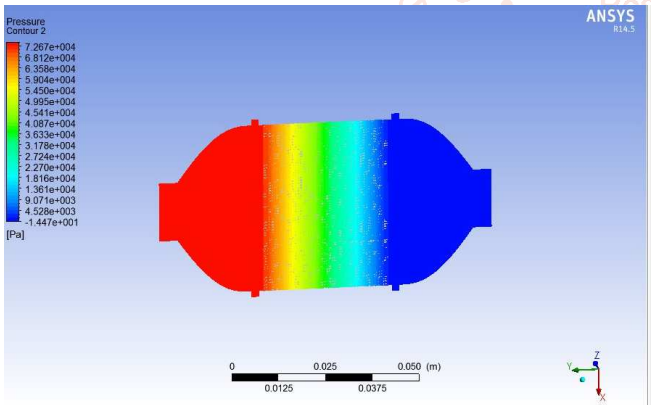

Figure 9 Pressure at 2000rpm for nitrogen

Mass Flow Rate	(kg/s)
inlet	0.0038079605
interior-substrate_body	0.079269324
outlet	-0.00042801513
Net	0.0033799454

Figure 10.Mass flow rate at 2000rpm for nitrogen

Mass-Weighted Average Velocity Magnitude	(m/s)
inlet	16.75
interior-substrate_body	2.9853907
outlet	2.2972658
Net	3.5809062

Figure 11.Mass weighted average velocity

Similar way the mass flow rate and mass weighted for Ethane and methane at different speeds are determined and tabulated

Steady state thermal analysis of catalytic Convertor

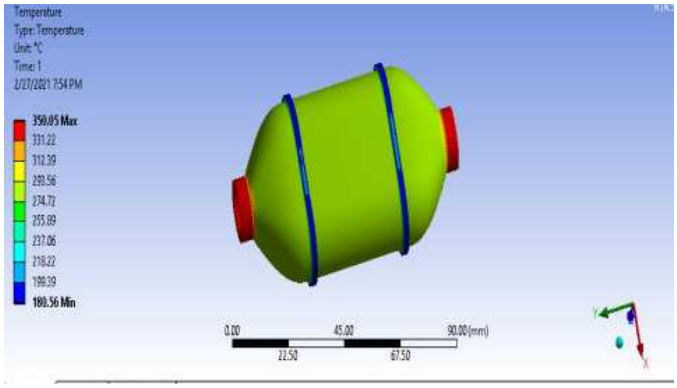

Figure 12 Temperature distribution for steel

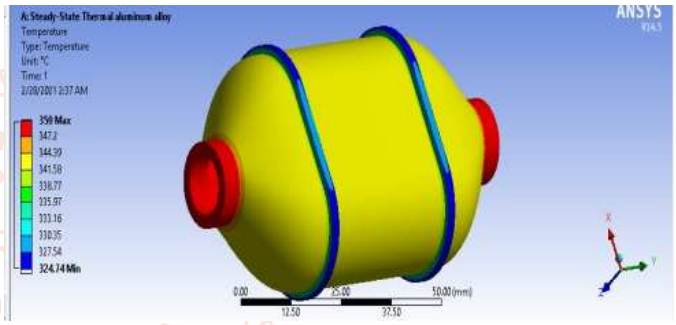

Figure 13 Temperature distribution for Aluminium

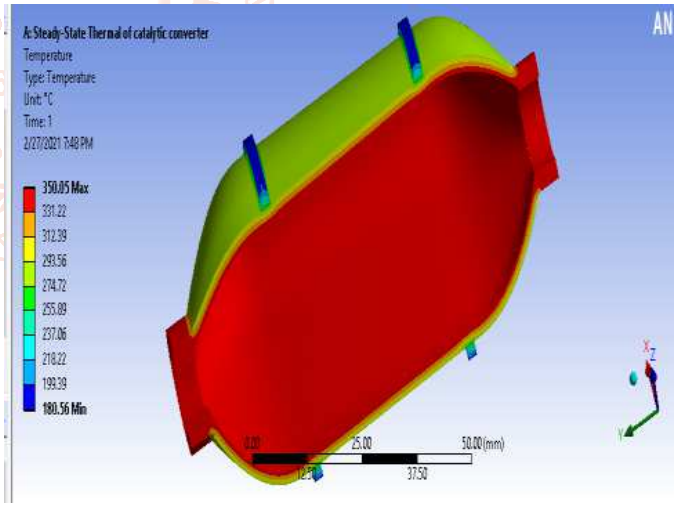

Figure 14.Heat Flux Distribution

Unsteady state/transient thermal analysis of catalytic convertor

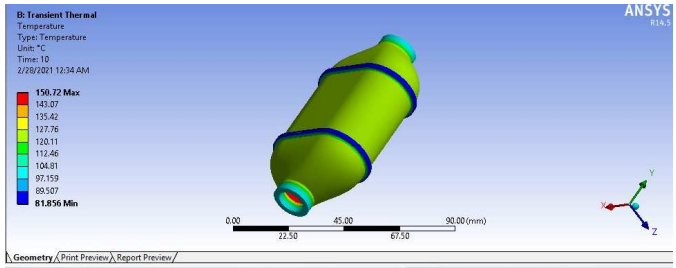

Figure 15.Heat flux Distribution for steel

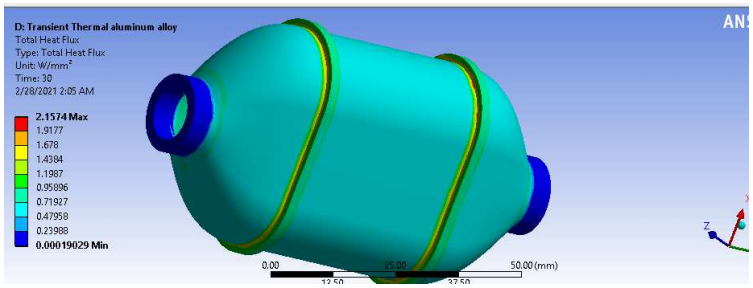

Figure 16.Temperature Distribution for steel

Similar way the heat flux and temperature distribution are determined and tabulated

RESULTS

Table 1 CFD analysis

fluid	Engine speed(rpm)	pressure (pa)	velocity (m/s)
Nitrogen	2000	7.27e+04	2.34e+01
	2500	9.20e+04	2.84e+01
Ethane	2000	4.28e+04	2.15e+01
	2500	5.49e+04	2.64e+01
Methane	2000	4.69e+04	2.35e+01
	2500	5.93e+04	2.85e+01

Table 2.Mass Flow Rate

Fluid	engine speed(rpm)	mass flow rate(kg/s)			
		inlet	outlet	interior substrate body	net flow rate
nitrogen	2000	0.003807	-0.000428015	0.07926	0.0033799
	2500	0.0047605	-0.00052024	0.099029	0.0042402
ethane	2000	0.004226233	-0.00048097	0.087718678	0.003745264
	2500	0.005283423	-0.000562752	0.10954842	0.004720671
methane	2000	0.002234918	-0.00024676	0.046537671	0.001988158
	2500	0.002793981	-0.000307021	0.05814116	0.00248696

Table 3.Mass weighted average velocity

fluid	engine speed(rpm)	mass weighted average velocity(m/s)			
		inlet	outlet	interior substrate body	net flow velocity
nitrogen	2000	16.75	2.297265	2.98539	3.5809
	2500	20.94	2.778597	3.37356803	4.471905
ethane	2000	16.75	2.241589	3.2272637	3.799628
	2500	20.94	2.61301	4.0376501	4.750803
methane	2000	16.75	2.260191	3.2098696	3.794471
	2500	20.94	2.806969	4.0161152	4.744567

Steady state thermal analysis

Table 4.Temperature

material	temperature		heat flux
	min	max	
stainless steel	180.56	350.05	1.2536
grey cast iron	278.06	350	1.7444
aluminum	324.74	350	1.9519

Table 5.Unsteady state thermal analysis results

Marterials	time (sec)	temperature (^{0}C)		Heat flux(w/mm^2)
		min	max	
stainless steel	10	81.856	150.72	0.81549
	20	133.49	259.03	0.84599
	30	177..17	350.98	1.253
Grey cast iron	10	120.63	150.04	0.81759
	20	198.64	250.04	1.2487
	30	276.07	350.05	1.8
aluminum	10	139.61	150.01	0.89796
	20	232.34	250.01	1.5106
	30	324.51	350.01	2.1574

Graphs

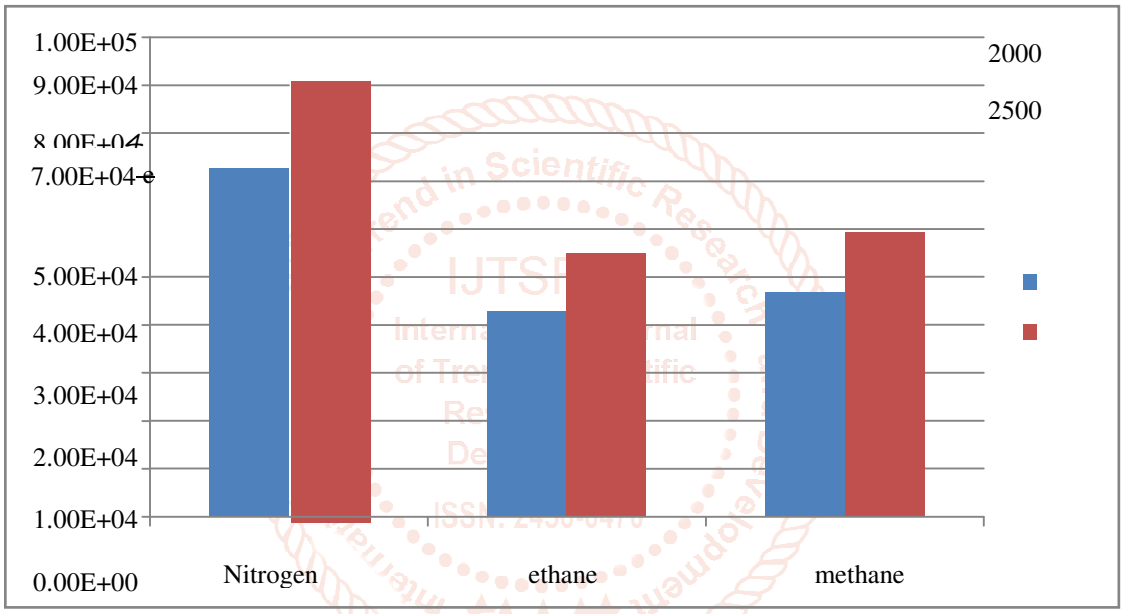

Figure 14 Pressure

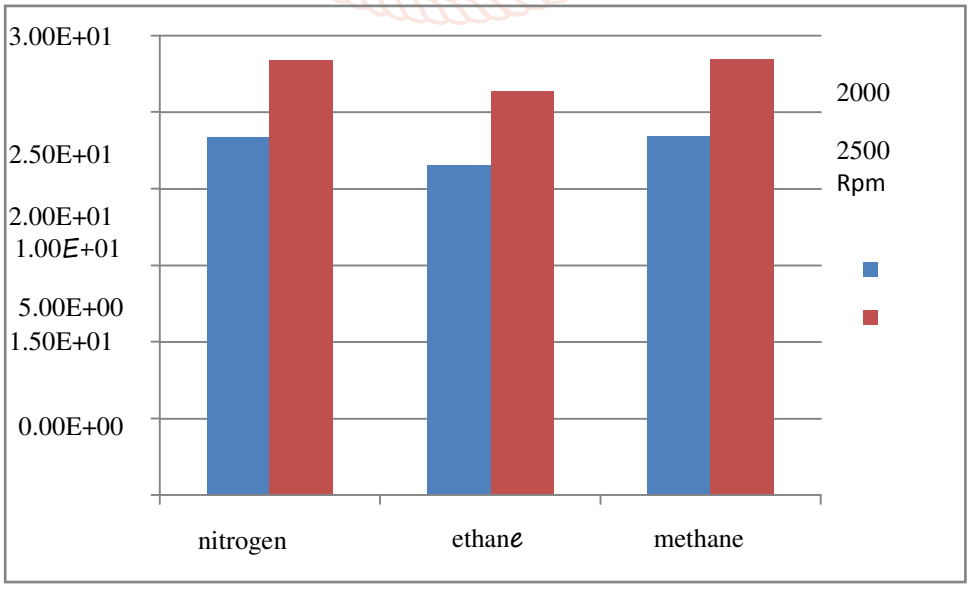

Figure 17.Velocity

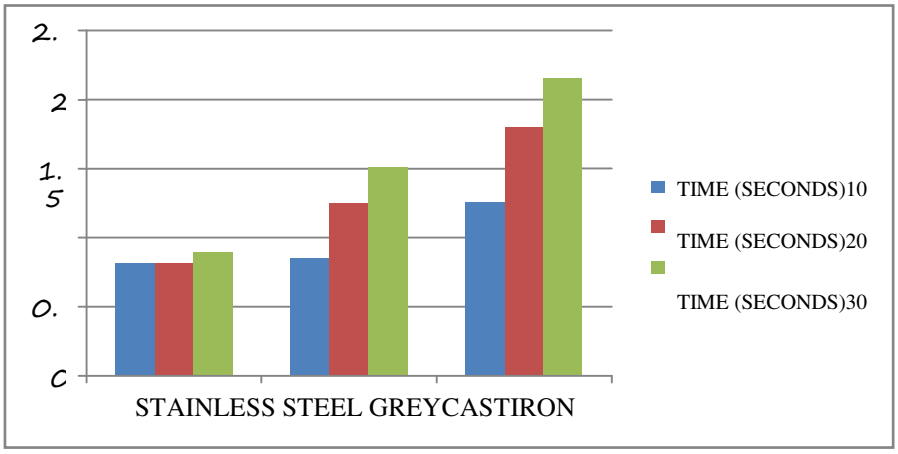

Figure 18.Unsteady state thermal analysis (Heat flux)

CONCLUSION

In this thesis, a catalytic converter is designed and developed for reduction in hazardous effluents. The catalytic converter is designed in CATIA V5 and analyzed by using CFD(Fluent) for three different materials which are Stainless Steel, Grey cast iron, Aluminium alloy at a time on different blended fluids Nitrogen and Air, Ethane and Methane at engine speeds 2000RPM, 2500RPM.It is observed from Steady and Transient state thermal Analysis Heat flux is less for Stainless steel than that of grey cast iron and aluminium and also it is observed from CFD analysis pressure and velocity are less in Ethane compared to other two gases at different speeds i.e 2000RPM and 2500RPM.The catalytic converter reduces the amount of both CO and HC while increase in the amount of carbon dioxide and it has been observed that reduction in pollutants in exhaust gases is more at 2000RPM.

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