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Design of an Automotive Exhaust System with Catalytic Converter and Method to Preparation there of

Yash Sudhirkumar Trivedi

Mechanical Department, PUNE University
1 / Harsidhdhi Park Society, Dalmill road, Surendranagar, Gujarat – 363001, India
Yashtrivedii007@gmail.com
[3]third.author@first-third.edu
[*]*Second Company*
Address Including Country Name
[2]second.author@second.com

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***Abstract*— The major challenges are to meet the environmental problems and adverse impact. This research addresses the above problems by providing automotive exhaust system having catalytic converter usable for both green and chemical technology. Car engines produce non-user friendly gases (such as like CO, NO NO_x and unburnt HC); and chemical reactions that take place within the catalytic converter change these gases into user friendly gases such as like CO_2, N_2, O_2 by using affordable catalysts. Thus this device controls the non-user friendly gases and converts into user friendly gases particularly suitable to human being. The present research has also aim to put CO_2 absorbing technology which will absorb CO_2 and made this device eco-friendly.**

***Keywords*— Catalytic Converter, Automobile Exhaust System, Catalysts, Green Technology.**

I. INTRODUCTION

There major challenges are to meet the environmental problems and adverse impact. This invention addresses the above problems by providing automotive exhaust system having catalytic converter usable for both green and chemical technology. In recent trend many vehicles manufactured and delivered on daily basis, so it's necessity to do some work on catalytic converter for controlling the pollution. Vehicles' engine produces non-user friendly gases (such as like CO, NO NOx and unburnt HC). So catalytic converter converts these gases into the user-friendly gases such as like CO_2, N_2, O_2. Though these chemical processes having occurs in sufficient peak temperatures with the presence of the catalysts (such as like platinum & Palladium). But in starting position, when engine starts, the catalytic converter could not able to do these conversion processes due to normal temperature. Thus these gases release directly to the atmosphere and polluted the air. Thus starting period of 5-7 minutes, the catalytic converter has to remain ineffectual and these called as name of cold-start emissions. The other problems with catalytic converter device are to clogged situations. In this case, we cannot be able to diagnose the catalytic converter without replacing it. This can be an expensive fix due high-priced of the catalysts. So these research work more particularly for affordable catalysts with additional CO_2 removal process. So the concept of eco-friendly can be also optimized.

II. PRELIMINARY DESIGN

The converter of the present research comprises a honeycomb structure coated with aluminium oxide with inside coating of not flammable bricks and outer body with material AISI 4140. Another coating with honeycomb structure of a material name is Fabrica which is preventing the heat release into the atmosphere.

A. Modified Design

The current model of the catalytic converter purifies automotive exhaust using sophisticated technologies. There are many types of catalysts that may be used in a catalytic converter, all of which are high-cost precious metals. Due to the cost of these metals, construction of the converter can become quite expensive if the catalytic converter structure is not designed efficiently. For example, today, no more than 4-9 grams of catalysts are used in a single converter [01]. The catalysts all require certain conditions in order to work effectively and efficiently, the main condition being high temperature.

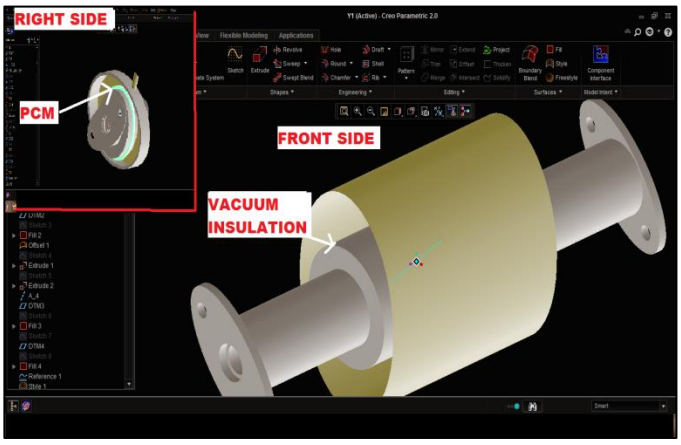

Fig. 1 Outline of the Catalytic Converter

This fig. 1 shows a heat retention system using the vacuum around the body which is restrict the heat transfer from the atmosphere and maintain the temperature rates up to sufficient level at starting position. Also provide phase change material (PCM) material purpose of preventing degradation of its body

cause from the high temperature rates. This is the part of design for newly developed catalytic converter.

B. Design for Accurate Conversations

The gases coming from the engine has a high velocity while passing through the catalytic converter device. So, complete conversation was carried out at the end although honeycomb structure helps to fall down the velocity of the exhaust gases, but pressure may increases due to that. So here designate the entering path of the exhaust which will helps the purification of the exhaust more particularly for velocity and pressure drops.

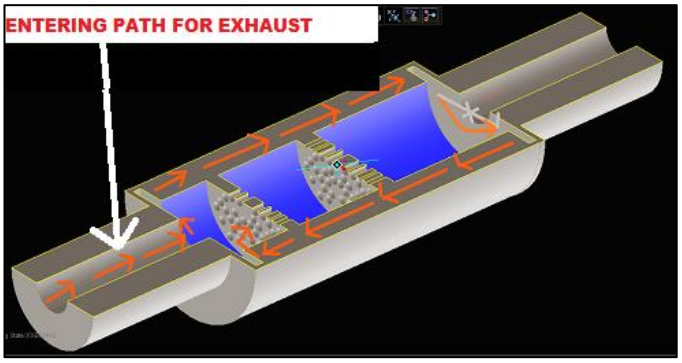

Fig. 2 Entering Path for Exhaust

As shown in the Fig. 2 the exhaust gases coming from the engine as designate path shown here. The benefits of this design are for accurate purifying conversion of the exhaust. Due to the wide area of travel, pressure drop decreases. The hot exhaust gases passes through the whole body of the converter, so the body temperature of converter may be increases gradually. Thus it also helpful for reduce the cold start emissions problem at primary level. For leak prevention due to the designate path, it is recommended to insulate it with Fabrica material that retains heat to release heat into the atmosphere and keep converter hot. Thus accurate conversion be possible.

C. Design for Soundwaves

The exhaust gases have a huge soundwaves which can distract the human being if we leave as it in the air. For that one device was develop which called as muffler which is situated at after the catalytic converter. But in current design it has also consider in the end of the catalytic converter's design itself which can make a muffler be optional.

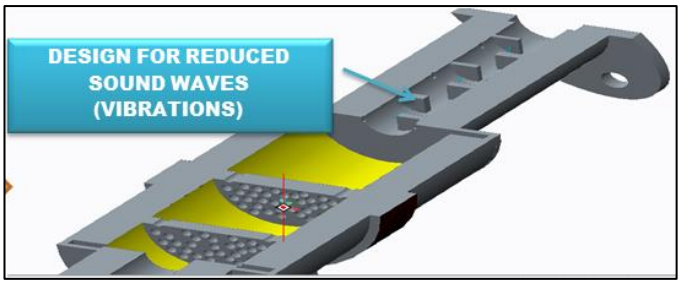

Fig. 3 Design for Sound waves

As shown in the Fig. 3, there is provided small building blocks at equilateral distances in the tail pipe of the catalytic converter. A muffler can be optional due to the advantage of the design at the end of the converter.

III. WORKING PRINCIPLE

The working procedures of the catalytic converter through newly developed design were described here. There was two affordable catalyst will be used as discussed before such like as cerium oxide (CeO_2) and porcelain substances. The one is oxidizing catalysts (such as like Cerium Oxide etc.) and another is for reducing catalyst (such as like porcelain etc.) The reason behind for choosing these catalysts due to its physical properties like, Non Flammable and it could not melt down even temp arises. Catalysts are needed to reduce emissions to acceptable levels without dramatically reducing performance and fuel economy. Cerium is an element that attracts oxygen. Under high oxygen conditions the cerium will absorb oxygen and allow NOx reduction to occur with greater efficiency. Under low oxygen conditions the cerium will release its stored oxygen to increase the oxidation efficiency of CO and HC conversions. Cerium is very important as catalyst. The cerium can allow as catalyst to continue reducing NOx at close to maximum efficiency without a rich mixture.

The main advantage use of cerium is that no need to air injection plug for air/fuel mixture in passenger car. Another advantage of cerium for loaded vehicles which must needed an air injection plug, from air/fuel mixture is continuously cycled from slightly rich to slightly lean, cerium can allow it to constantly operate at maximum efficiency.

Another catalyst was porcelain which is use for the purpose of oxidization and its main advantage is to tolerate hot atmosphere and continues its conversion even a high temp (could not melt down).

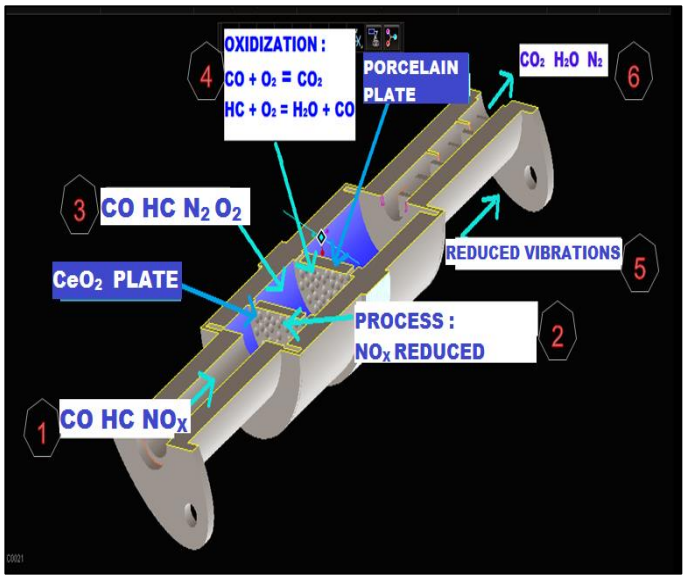

Fig. 4 Working Principle of Catalytic Converter

As shown in the Fig. 4, the catalytic converter consists of two catalysts like as: cerium oxide and porcelain which are affordable to our society. According to the figure that is mentioned by numbering, so we will understand the whole working procedure one by one.

1) *Entering path for Exhaust:* The exhaust gases coming from the vehicles' engine enters the catalytic converter with high velocity. As defined in Fig. 2 , the exhaust gases not directly go through the catalytic converter, but its circulate the converter's body as designate path and then enters into it for the chemical conversations .

2) *Reduction process*: When exhaust enters firstly reduction process occurs in the presence of the catalyst cerium oxide (CeO_2). The gases like NO, NO_x are reduced from the exhaust mixture. The cerium can allow as catalyst to continue reducing NOx at close to maximum efficiency without a rich mixture.

- $NO_x \rightarrow N_2 + O_2$

3) Reduced exhaust Gases: After the completion of the reduction process we have the gases such as like N_2, O_2, CO and unburnt hydrocarbon (HC). Here one point is considered that this design is as following process by reduction-oxidization, while in traditional catalytic converter there is an oxidization-reduction processes occurs. The advantage of this design is that when reduction process is complete we have already oxygen (O_2) which can be helpful for oxidization processes ahead. Thus arrangements drastically reduced the work of the oxygen sensor plug.

4) Oxidization Process: The oxidization process having occurs in the second mode of the catalytic converter in the presence of the porcelain catalysts. As we discussed ago, it has already oxygen (O_2) for further process ahead and it will reduce the work load on the oxygen sensor plug.

- $CO + O_2 \rightarrow CO_2$
- $HC + O_2 \rightarrow H_2O + CO_2$

5) *Soundwaves Reduced:* In the end of the converter, it has designed some building blocks at equilateral distances which will helpful to reduce the soundwaves at primary level. Mufflers can be optional due to these arrangements.

6) User-friendly Gases: It shows the user-friendly gases such as like N_2, O_2, H_2O and CO_2. After the competitions of the all the chemical processes, catalytic converter converts the non-user friendly gases into the user-friendly gases which is desirable and safe to release into the atmosphere.

Thus we succeed to get the user-friendly gases which are safe to inhale and can release into the air, but in case of CO_2 it is not desirable to our environment. In many environmental diseases the CO_2 is key role and its passive effects on the environment such as like greenhouse effect etc. Today many organizations are required to respond to environmental and social demands. So it must do some effort for design aspects in forward step to the environment.

As the beneficial to our environment, introduce to the CO_2 removal process. After the catalytic converter device, put a small pipes which contains the zeolite material that absorbs the CO_2 on its surface. A pipes works as membranes such like it has small holes into it and its diagonal to the pipe geometry. The concept behind the diagonal holes in the pipes that CO_2 has atomic-weight which is higher compare to other exhaust gases (such as like N_2, O_2, H_2O). So the CO_2 has less velocity to flies up to air and keep it at to the floor where the zeolite as it obviously absorbs the CO_2 and other remaining exhaust gases are easily flies and can be easily going through to the atmospheric air. More accurate work put more numbers of the CO_2 removal pipes as one by one. Due to the absorption process it may need to be maintained means it can be replaced in such an equal duration of time.

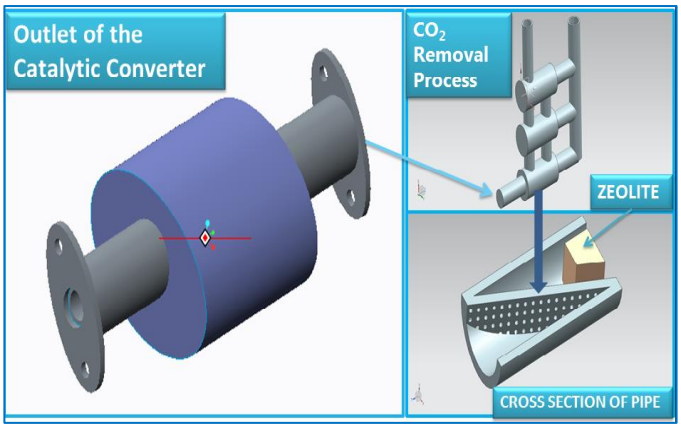

Fig. 5 CO_2 Removal Process

As shown in the Fig. 5 the CO_2 removal pipes consist after the end of the catalytic converter. That pipes contains zeolite material that absorbs the CO_2 on its surface. That contains the zeolite which is sufficient option for CO_2 absorption and proves our eco-friendly concept. Zeolites are highly porous rocks—think of a sponge made of stone—and while they occur in nature, they can be manufactured as well. Their toughness, high surface area (a gram of zeolite can have hundreds of square meters of surface in its myriad internal chambers) and ability to be reused hundreds of times makes them ideal candidates for filtering gas mixtures. If an unwanted molecule in the gas mixture is found to stick to a zeolite, passing the mixture through it can scrub the gas of many impurities, so here zeolites are used for filters. Thus CO_2 can be trapped and our concept eco-friendly can be optimized.

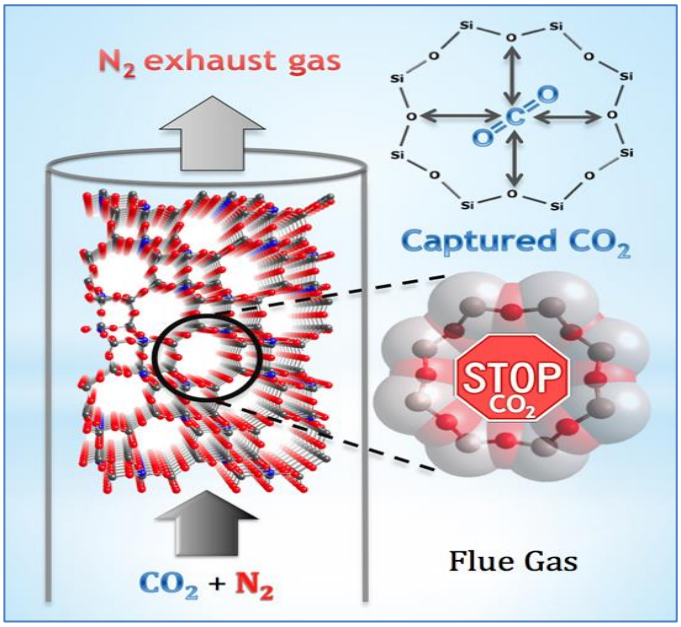

Fig. 6 CO_2 Trapped Mechanism [07]

After the absorbing the CO_2, the system needs to be maintained at equal interval time. At that situation the pipes contains zeolite must replace, but they no need to be varnished because they can be recycled at many industries which are actually need the CO_2. So, it is also beneficial at industrial level for production of CO_2. Once again the environment should praise by this green innovative technology.

IV. Analysis and Discussions

An improvement of catalytic converter design requires better fundamental understanding of complex processes taking place involving fluid flow, heat and mass transfer, and chemical reactions. The catalytic converter model construction was carried out by reverse engineering technique. Based on the dimensions obtained from reverse engineering technique CAD modelling was done. The generation of catalytic converter geometry involved wire frame, surface and solid modeling [04]. Geometric modeling was carried out by the PRO-E/CREO elements 2.0. The features involved in the geometric modeling were wire-frame, surface and solid modeling. After the extraction of fluid domain, catalytic converter was imported to ANSYS 14.0 to generate the grid. The model was discretised along with boundary layer. Discretization is the method of approximating the differential equations by a system of algebraic equations for the variables at some set of discrete locations in space and time. The discrete locations are referred to as the grid or the mesh.

Specifications are defined with three basic parameter name, type and entity as in FLUENT. In the present analysis, after the grid generation boundary condition was applied. FLUENT was used as solver. Mass flow was imposed at the inlet, and pressure applied at the outlet. Boundary specifications of the catalytic converter were given below in table 1.

Table I
Boundary Specification for Emissions [09]

Temperature (K)	*EMISSIONS*					
	Carbon monoxide (CO)			Nitrogen oxide (NO)		
	Mass fraction at inlet	Mass fraction at outlet	Conversion efficiency	Mass fraction at inlet	Mass fraction at outlet	Conversion efficiency
300	0.0142	0	0	0.001	0	0
400	0.0142	0.0003	0.021126761	0.001	0.00003	0.03
500	0.0142	0.00388	0.273239437	0.001	0.000204	0.204
600	0.0142	0.00525	0.36971831	0.001	0.000341	0.341
700	0.0142	0.00556	0.391549296	0.001	0.000373	0.373
800	0.0142	0.00583	0.41056338	0.001	0.000402	0.402
900	0.0142	0.00606	0.426760563	0.001	0.000423	0.423
1000	0.0142	0.00626	0.44084507	0.001	0.000444	0.444
1100	0.0142	0.00636	0.447887324	0.001	0.000456	0.456

The inlet and outlet cone of catalytic converter are straight, hence a good flow is expected. It is found from the computation that the flow is very uniform in the substrate. The maximum pressure drop occurs due to porous media. The total pressure drop of catalytic converter is about 7kPa, of which 88% is from the substrate, 7% from the inlet cone, and 5% from the outlet cone. The flow in the catalytic converter is determined by the geometrical configuration, the flow resistance characteristics of the substrate and the Reynolds number [09].

It is clear that when the mass flow rate increases, the pressure drop also increases. This is due to the presence of porous media. From the contours, it is observed that the pressure near the inlet of porous media is more compared to the outlet of porous media. Thus the porous media greatly influences the pressure drop. Pressure contours indicates that the calculated flow uniformity index at the front face of the substrate is decreased with the increasing of the Reynolds number, and increased with the increasing of the cell density. The higher pressure is located around the catalyst entrance and the centerline.

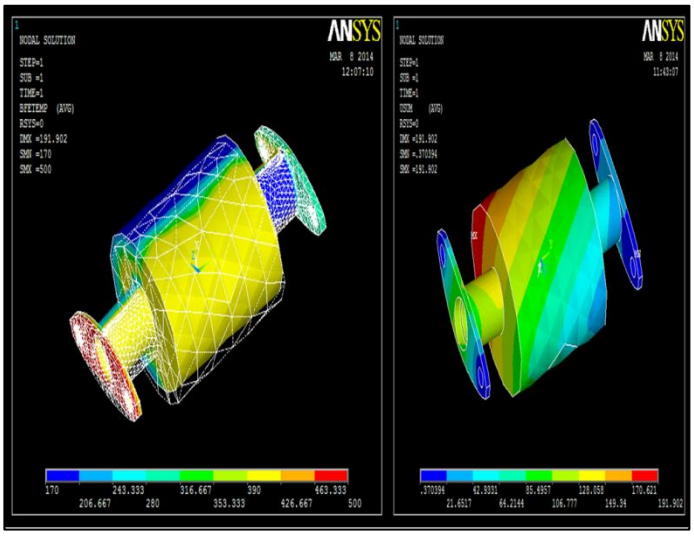

Fig. 7 Analysis of the Catalytic Converter

Analysis of the catalytic converter is shown in the Fig. 7 through ANSYS 14.0. It also describes the load on the catalytic converter through the vectors analysis which is indicated first. Then temperature analysis are having occurs to check whether the catalytic converter's body are extinguish or not through the higher rate of the temperature.

The catalytic converter prototypes have been extensively evaluated for their performance, durability and for others parameters. The typical oxidative type catalytic converter performs with CO and HC mass conversion efficiencies of 50 to 60 per cent and 80 to 90 per cent, respectively, for four-wheeler vehicles. CO and HC conversion efficiencies for two-wheeler catalytic converters are 65 to 75 per cent and 55 to 65 per cent, respectively. These conversion efficiencies are sufficient for meeting present emissions norms. Durability of the converter has also been evaluated following the field trial procedure on in-house, old vehicles. The durability estimated is about 50,000 km, which confirm its sustainability for the retort it mechanism [04].

While a sophisticated piece of technology, the catalytic converter can be damaged. Carbon contamination occurs when a series of engine malfunctions or an excessive number of successive short trips are drive. This creates an extreme excess of gasoline, causing a very rich mixture to run through the converter. An overly rich gas stream entering the converter can not only fail to oxidize the hydrocarbons and carbon monoxide entering the converter, but also overheat the system and cause substrate meltdown (damage to the converter's structure) [06].

If the catalysts coating the honeycomb structure are obstructed, the efficiency of the catalytic converter significantly decreases. Almost all automobiles today use unleaded gasoline, but if lead were to enter the engine and get burned, a residue would be produced that covers the catalytic materials and prevents them from filtering exhaust. The lead residue could also coat the oxygen sensor and prevent the correct ratio of oxygen/gasoline from entering the converter. An octane rating measures the flammability of a fuel, and a higher rating means a safer fuel which cannot be combusted as easily.

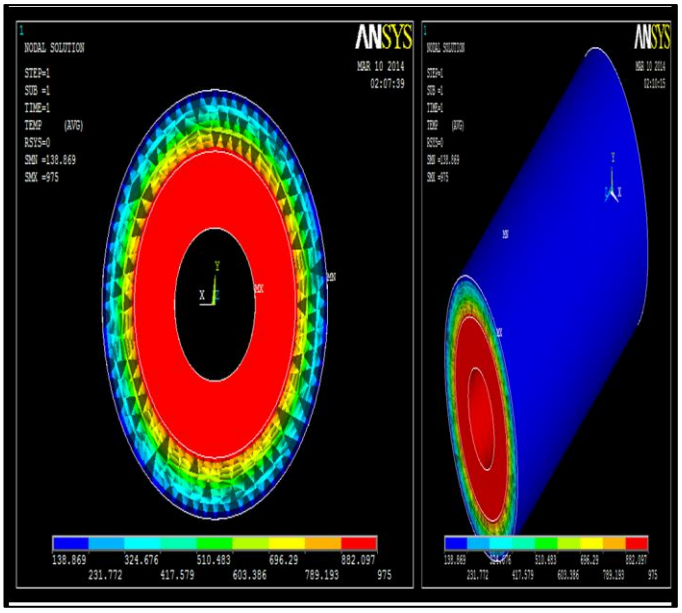

Fig. 8 CO_2 Absorber Pipes Analysis

Analysis of the CO_2 absorber pipes are defined here in Fig. 8 with front and side view of that. As shown in the figure internal temperature of the body of pipes are too high due to high velocity of the exhaust gases. But the outside body of the pipes are tolerated due to even a rate of change of temperature is higher.

Now Check for the Design:

a) Torque transmitted, $T = \frac{\pi D^2}{2} \times \tau_c \times t_f$

$$215 \times 10^3 = \frac{\pi \times 30^2}{2} \times \tau_c \times 17.5$$

Allowable Stress, τ_c = 59.6 MPa $\cong 60\ MPa$

b) For AISI 4140,

Max. Permissible Stress is σ_t = 215 MPa.

c) For Bolts (studs),

Torque transmitted, $T = \frac{\pi^2}{16} \times \mu\, {d_b}^2 \times \tau_c \times n \times d$

$$2865 \times 10^3 = \frac{\pi^2}{16} \times 0.3 \times 18.42^2 \times \tau_c \times 6 \times 19$$

Allowable Stress, τ_c = 66.6 MPa $\cong 67\ MPa$

d) $\tau_{c(flange)} < \sigma_t$, $\tau_{c(bolt)} < \sigma_t$

e) Hence our design is safe.

V. Conclusions

With the current research on catalytic converters, it is possible to for now a days where automobiles are no longer known to pollute and damage the environment. As well as being environmentally friendly, the automobile industry will benefit from this new catalytic converter. Automobile manufacturers will no longer be responsible for so much environmental damage due to the advanced catalytic converter. It is also applicable on the low temperature operated vehicles (such as like CNG etc.). By absorbing CO_2, it is praise for our environment and could not be responsible for environmental aspects. In more addition, further future research scope also available for reading catalytic converter that automobile vehicles' engine many non-user friendly gases produced but here only consider three main gases (such as like CO, NO_x, HC etc.) which were spread the emissions in higher rates, whereas it has some more non-user friendly gases (such as like SO_2, PM_{10}, $PM_{2.5}$ etc.) which fallen out from the engine in small amounts. Thus we can make this device more accurate and pollution issues through automobile vehicles will be eliminated.

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