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CFD ANALYSIS OF CATALYTIC CONVERTER

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ABSTRACT:

Diesel engines have high efficiency, durability, and reliability together with their low-operating cost. These important features make them the most preferred engines especially for heavy-duty vehicles. The interest in diesel engines has risen substantially day by day. In addition to the widespread use of these engines with many advantages, they play an important role in environmental pollution problems worldwide. Diesel engines are considered as one of the largest contributors to environmental pollution caused by exhaust emissions, and they are responsible for several health problems as well. The four main pollutant emissions from diesel engines (carbon monoxide-CO, hydrocarbons-HC, particulate matter-PM and nitrogen oxides-NOx) and control systems for these emissions (diesel oxidation catalyst, diesel particulate filter and selective catalytic reduction) are discussed. Each type of emissions and control systems is comprehensively examined. The present project deals with the comparison of CFD simulation to fabricated catalytic filter results used as emission controller suitable for clamping to diesel engine for optimizing the control of emissions before and after usage.

Keywords: Diesel engine, Emission control system, catalytic converter.

INTRODUCTION

Diesel exhaust soot is the visible cloud of black carbon-containing smoke that appears on engine start-up and during normal diesel engine operation. Black carbon is hazardous to health and presents a range of other issues, including visible product contamination and soiling. It is also believed that black carbon is a contributory factor in climate change. This technical paper aims to clarify the issues surrounding exhaust soot and presents information designed to assist in the decision-making process of how best to reduce black carbon emissions from diesel exhausts.

1.1 Particulate Matter (PM)

In a theoretically perfect combustion, carbon dioxide, water and nitrogen are the end products. In reality, the incomplete combustion of diesel fuel results in emissions that include oxides of nitrogen (NOx), carbon monoxide (CO), carbon dioxide (CO2), water (H2O) and unburned hydrocarbons (HC). There are also unborn carbon particles, as well as engine oils, debris, soot and ash particulates, which are known as particulate matter (PM). This diesel particulate matter (DPM) is the visible cloud of black smoke that appears from engine start-up and continues to

appear when the engine is running. DPMs can be categorized into two groups
PM10 - Particles of 2.5 microns to 10 microns, and

PM2.5 - Particles of less than 2.5 microns in size. Although most Diesel Particulates are very small, more than 99% are in the sub-micrometer range.

1.2 The concerns associated with DPM

Climate change is something that directly affects us all and is just one of the concerns associated with diesel exhaust emissions. The main issues surrounding black carbon soot being:

- Health DPM has been identified by health experts as contributing to a variety of lung related illnesses. Exposure to DPM has been linked to acute short-term symptoms such as headaches, nausea, and irritation of the eyes, nose and throat. Long-term exposure can lead to chronic and more serious health problems such as cardiovascular disease and lung cancer.

- Inhalation The smallest particles have the worst health implications because of their ability to penetrate deep into lung tissue. They easily bind with other toxins in the environment, thereby increasing the hazards of particle inhalation.

- Confined Spaces Machinery operating in confined or enclosed spaces – for example in tunnels, mines, and quarries, or in factories and warehouses where ventilation is limited – pose a greater health risk to operatives and anyone in the vicinity of that equipment.

- Air Quality In addition to the health concerns mentioned above, the pollution emitted by diesel engines contributes greatly to air quality problems such as haze and smog, both of which restrict visibility and can cause irritation of the eyes, nose and throat. Furthermore, diesel exhaust fumes contribute to ozone formation, acid rain, and climate change.

Contamination DPM can also contaminate products and packaging in factories and warehouses where DPMs are present in the atmosphere. In the wider environment DPM contaminates foliage and soils buildings, an all too common sight in urban areas.

1.3 How can the black smoke are reduced

The industry has been developing innovative ideas to reduce exhaust emissions for many years. A number of solutions are available and these range from Exhaust Gas Recirculation (EGR) to Dual Fuel conversions. The most effective solutions are designed specifically to deal with particulates and can reduce the DPM emissions in the exhaust by up to 99%, from startup. These systems are known as Diesel Particulate Filters or Soot Filters.

	STANDBY/LOW USAGE	PRIME/HIGH USAGE
PM	Non-regenerative	Regenerative
CO	Catalytic converter	Catalytic converter
HC	Catalytic converter	Catalytic converter
PM,CO+HC	Non-regenartive+catalytic converter	Regenerative+catalytic converter

As each application is unique, the above table is for guidance only. GenCat engineers are happy to assist in the selection of appropriate Diesel Particulate Filters or Catalytic Convertors tailored to your specific requirements.

1.6 Catalytic Converters

Catalytic converters are separate systems that reduce carbon monoxide (CO), unburned hydrocarbons (HC) and aldehydes. These exhaust emissions are generally associated with contributing significantly to atmospheric pollution problems and are responsible for irritation to the eyes and respiratory system. They can also cause nausea, headaches and tiredness. These effects are further compounded in enclosed spaces such as warehouses, tunnels and mines.

LITARATURE REVIEW

Several techniques have been researched and developed to abate hazardous emission constituents from diesel engines at the source level. Some of such extensively investigated techniques are:

- Variations of Injection Pressure and Nozzle Geometry
- Pre-Mixed Combustion
- Water Injection or combinations of two or more of above.
- Retarded and split fuel injection
- Exhaust Gas Recirculation (EGR)

2.2 Emission control systems for diesel engine vehicles

In today's world, environmental protection has advanced to become a topic of central concern. Many agencies and organizations are tried to prevent the damage on environment and human health caused by greenhouse gases and pollutant emissions. Due to the adverse effects of diesel emissions on health and environment, governments put forward to the requirements for permissible exhaust emission standards.

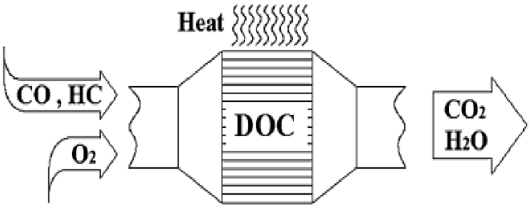


Fig. 2.2 Diesel oxidation catalyst

Europe has developed Euro standards which have continuously been lowered The limits are defined in mass per The emission values which have been more stringent day by day obliged the vehicle manufacturers to work on reducing pollutant emission from vehicles. In the studies that have been carried out for decades, engine modifications, electronic controlled fuel injections systems, and improvement fuel properties have been focused on. However, these measures have failed to achieve emission reduction determined by standards. The desired emission levels can be achieved only by means of after treatment emission control systems. Vehicles are equipped with emission control systems to meet the actual emissions standards and requirements. With emission control systems, pollutants from the exhaust can be eliminated after it leaves the engine, just before it is emitted into the air (Prasad and Bella 2010; Bosch 2005).

2.3smoke filtration

end force the diesel particulates matters through the porous substrate walls, which act as a mechanical filter (Fig. 3). As soot

particles pass through the walls, they are transported the pore walls by diffusion where they adhere. This filter has a large of parallel mostly square channels. The thickness of the channel walls is typically 300–400 lm. Channel size is specified by their cell density (Typical value: 100–300 cpsi) (Kuki et al. 2004; Ohno et al. 2002; and Yamamoto 2012). The higher regeneration temperature and large amount of energy for heat supply are serious problems for active regeneration. While the temperatures as high as melting point of filter generates to failure of DPF, the necessity of energy for heating increases the production cost of system due to complex supplements. These negative effects regard the active regeneration as being out of preference. Unlike in the active regeneration, in passive regeneration of DPF, the oxidation of PMs occurs at the exhaust gas temperature by catalytic combustion promoted by depositing suitable catalysts within the trap itself. PM is oxidized by an ongoing catalytic reaction process that uses no additional fuel. Under a temperature range between 200 and 450 _C, small amounts of NO2 will promote the continuous oxidation of the deposited carbon particles. This is the basis of the continuously regenerating trap (CRT) which uses NO2 continuously to oxide soot within relatively low temperatures over a DPF (York et al. 2007,
[4] Allansson et al. 2002).

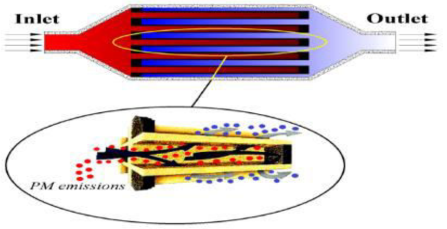


Fig 2.3 shows that Filtration of DPF

There are subsequently two types of regeneration processes of DPFs commonly referred as active regeneration and passive regeneration. Active regeneration can be periodically applied to DPFs in which trapped soot is removed through a controlled oxidation with O2 at 5500C or higher temperatures [5] (Jeguirim et al. 2005).

Problem statement

Many policies have been imposed worldwide in recent years to reduce negative effects of diesel engine emissions on human health and environment. Many researchers have been carried out on both diesel exhaust pollutant emissions and after treatment emission control technologies. The emissions from diesel engines and their control systems are reviewed and there is a need to develop of pollutant filtration in a practical testing system to check the minimum emission rate.

Objectives

- To study the present using emission control systems.
- To study the fabrication process of making filter type emission control equipment.
- To check the present emissions in diesel engine with chemical ratios.
- To check the emissions after assembling new filter.
- To compare both the emission ratios before and after practically.

MATERIALS, METHODS, DESIGN

3.1 Materials:

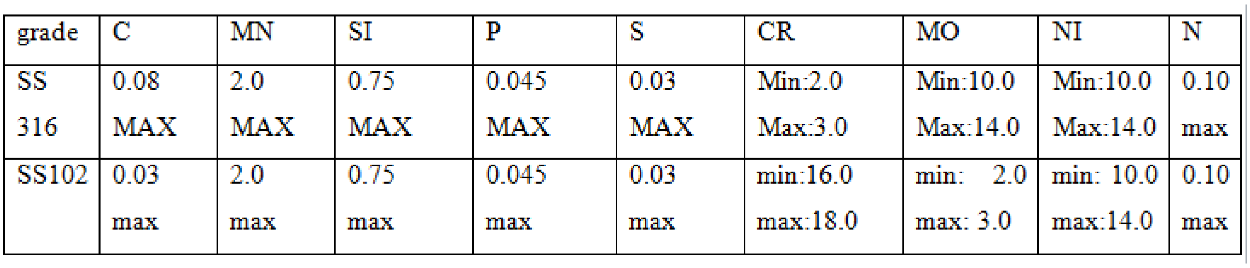
Stainless steel 316:

Stain less steels are iron base alloys containing 10.5% or more chromium. they have used for many industrial architectural chemical and consumer applications for over a half centuryCurrently there are being marketed a number of stain less steels originally recognized by the American iron and steel intuits (AISI) as standard alloys .also commercially available are property stain less steels with special characteristics A stainless steel in the singular sense as if it were one material .actually there are over fifty stain less steel alloys there are classification are used to identify stain less steels

There are:

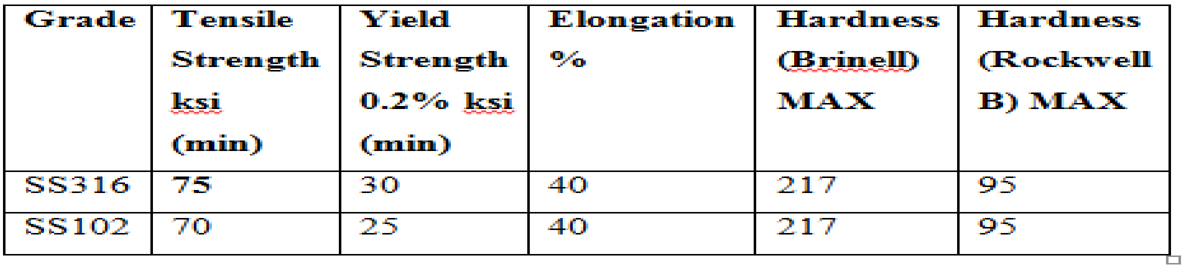
1. Metallurgical structure
2. The AISI numbering system (Namely ‘’200,300,400. Series numbers)
3. The unified numbering system

The 3.1 Table shows that chemical properties



grade	C	MN	SI	P	S	CR	MO	NI	N
SS 316	0.08 MAX	2.0 MAX	0.75 MAX	0.045 MAX	0.03 MAX	Min:2.0 Max:3.0	Min:10.0 Max:14.0	Min:10.0 Max:14.0	0.10 max
SS102	0.03 max	2.0 max	0.75 max	0.045 max	0.03 max	min:16.0 max:18.0	min: 2.0 max: 3.0	min: 10.0 max:14.0	0.10 max

MECHANICAL PROPERTIES



Grade	Tensile Strength ksi (min)	Yield Strength 0.2% ksi (min)	Elongation %	Hardness (Brinell) MAX	Hardness (Rockwell B) MAX
SS316	75	30	40	217	95
SS102	70	25	40	217	95

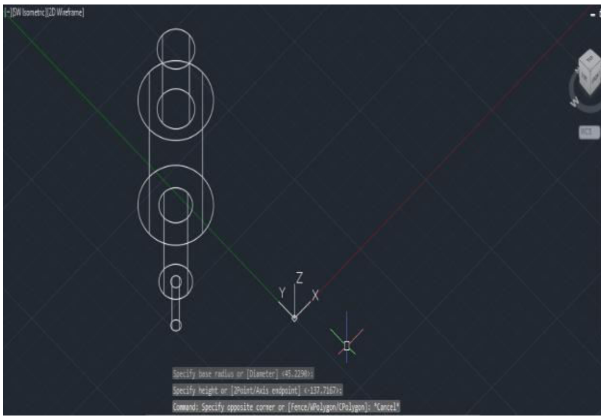
PHYSICAL PROPERTIES

Density lbm/in3	Thermal Conductivity (BTU/h ft. °F)	Electrical Resistivity (in x 10-6)	Modulus of Elasticity (psi x 106	Coefficient of Thermal Expansion (in/in)/°F x 10-6	Specific Heat (BTU/lb/°F)	Melting Range (°F)
0.29 at 68°F	100.8 at 68 212°F	29.1 at 68°F	29	8.9 at 32 – 212°F	0.108 at 68°F	2500 to 2550

3.2 STAINLESS STEEL - GRADE 316 PROPERTIES

Type 316 is an austenitic chromium nickel stainless steel containing molybdenum. This addition increases general corrosion resistance, improves resistance to pitting from chloride ion solutions, and provides increased strength at elevated temperatures. Properties are similar to those of Type 304 except that this alloy is somewhat stronger at elevated temperatures. Corrosion resistance is improved, particularly against sulfuric, hydrochloric, acetic, formic and tartaric acids; acid sulfates and alkaline chlorides, optimum corrosion resistance.

For instance, the component LEDAS Geometry Comparison based on C3D kernel can be integrated in CAD system (like Autodesk Inventor, [18]) to compare 3D models and pinpoint all of the differences between them.



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Specify base radius or [Diameter] <45.2290>:
Specify height or [2Point/Axis endpoint] <-137.7167>:
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Figure plane view of the catalytic filter

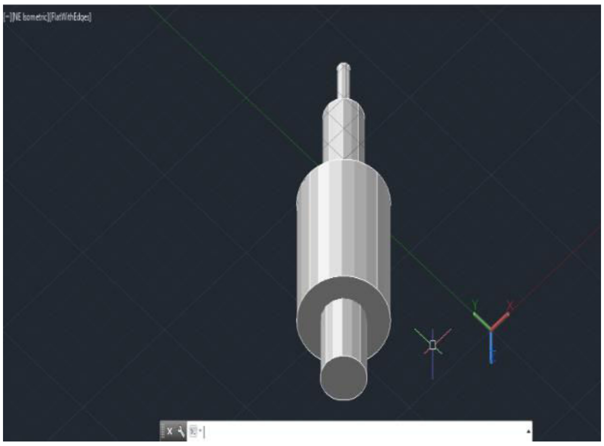
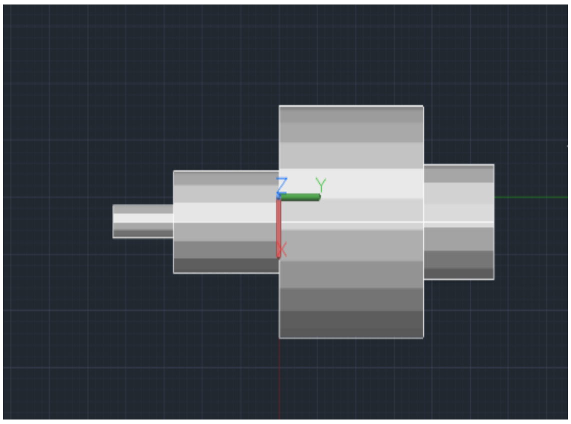
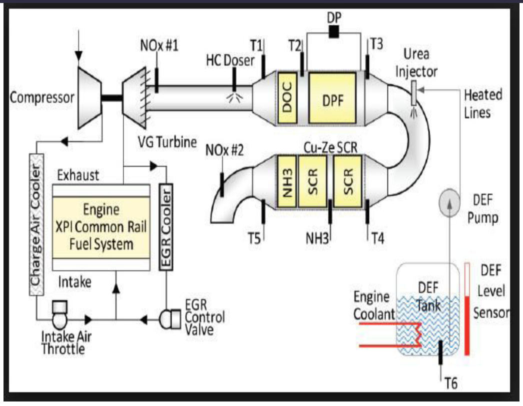


Figure shows that front catalytic convert filter view



The figure shows that catalytic convert filter of the cad model



Diesel engine common rail catalytic convert filter system: The diesel engine is an auto-ignition engine in which fuel and air are mixed inside the engine. The air required for combustion is highly compressed inside the combustion chamber. This generates high temperatures which are sufficient for the diesel fuel to ignite spontaneously when it is injected into the cylinder. Air pollution can harm human health and damage all the elements of the ecosystem. For nearly four decades, state and federal governments have controlled the emission of pollutants through permits with enforceable requirements and have measured and monitored pollution levels in the air.

3.4 WELDING PROCESS OF CATALYTIC FILTER

The normal TIG welding process of catalytic convert filterusing materials is ss316,ss102 normal Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenously welds, do not require it. A constant-current welding power supply produces electrical energy, which is conducted across the arc through a column of highly ionized gas and metal vapors known as a plasma.

The figure shows that normal TIG welding process of smoke filterGTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. A related process, plasma arc welding, uses a slightly different welding torch to create a more focused welding arc and as a result is often automated.

The figure shows that TIG welded component (SS316,SS102)

Smoke sensor for diesel engines. The sensor is intended to provide a means of detecting smoke levels that exceed certain pre-defined limits. ...EGR levels were adjusted to vary exhaust smoke levels at a fixed speed/load test point. Smoke measurements were provided by an available FOR 415s variable sampling smoke meter. ...Engine dynamometer tests were carried out using a heavy duty diesel engine equipped with a laboratory EGR system. EGR levels were adjusted to vary exhaust smoke levels at a fixed speed/load test point.

3.5Fabrication of the catalytic convert filter:

Stainless Steel Processes

The final operation after fabrication or heat treatment is cleaning to remove surface contamination and restore corrosion resistance of the exposed surfaces. Degreasing to remove cutting oils, grease, crayon markings, fingerprints, dirt, grime and other organic residues is the first step.

Degreasing:

Non-chlorinated solvents should be used in order to avoid leaving residues of chloride ions in crevices and other locations where they can initiate crevice attack, pitting, and/or stress corrosion later on when the equipment is placed in service.

Machined Components:

After degreasing, machined components are sometimes “passivated” in 10% nitric acid. Nitric acid enhances the natural oxide surface film.

Using the fabrication materials:

Stainless steel 316,

Stain less steel 102.

Fabrications:

After degreasing, metallic surface contaminants such as iron embedded in fabrication shop forming and handling, weld splatter, heat tint, inclusions and other metallic particles must be removed in order to restore the inherent corrosion resistance of the stainless steel surface.

Nitric-HF pickling, (10% HNO3, 2% HF at 49C to 60C (120 to 140F), is the most widely used and effective method removing metallic surface contamination. Pickling may be done by immersion or locally using a pickling paste.

Electro Polishing:

Electro polishing is using oxalic or phosphoric acid for the electrolyte; a copper bar or plate for the cathode can be equally effective. Electro-polishing may be done locally to remove heat tint alongside of welds or over the whole surface.

Both pickling and electro polishing remove a layer several atoms deep from the surface. Removal of the surface layer has the further benefit of removing surface layers that may have become somewhat impoverished in chromium during the final heat treatment operation.

Glass Bead or Walnut Shell Blasting:

Glass bead or walnut shell blasting are very effective in removing metallic surface contamination without damaging the surface. It is sometimes necessary to resort to blasting with clean sand to restore heavily contaminated surfaces such as tank bottoms, but care must be taken to be certain the sand is truly clean, is not recycled and does not roughen the surface. Steel shot blasting should not be used as it will contaminate the stainless steel with an iron deposit.

Stainless steel wire brushing or light grinding with clean aluminum oxide abrasive discs or flapper wheels are helpful. Grinding or polishing with grinding wheels or continuous belt sanders tend to overheat the surface layers to the point where resistance cannot be fully restored even with subsequent pickling.

The figure shows that fabrication material of smoke filter

The figure shows that catalytic convert filterss316 material

The figure shows that housing of the catalytic convert filter

The figure shows that jaley of the smoke filter

The figure shows that part of catalytic convert filter

RESULTS

The table 4.1 shows that practical values of normal diesel engine cold shot emissions

Emission percentages	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	PM (g/kWh)
Hyd-1	0.45	1.1	0.28	0.712
Hyd-2	4	1.2	2.48	0.776
Hyd-3	1.5	0.66	1.336	0.416
Hyd-4	1.4	0.46	0.88	3.69
Hyd-5	1.3	0.13	0.888	0.84
Hyd-6	1.21	0.11	0.621	0.09

The table 4.2 shows that practical values of normal diesel engine hot shot emissions

Emission percentages	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	PM (g/kWh)
Hyd-1	5.17	1.27	3.15	0.27
Hyd-2	38.3	38.3	36.34	37.3
Hyd-3	24.15	1.62	22.14	0.62
Hyd-4	17.25	5.28	15.23	4.28
Hyd-5	16.1	5.05	14.01	4.05
Hyd-6	14.95	1.48	12.91	0.48

Table 4.3 shows that Normal diesel engine cold shot emission

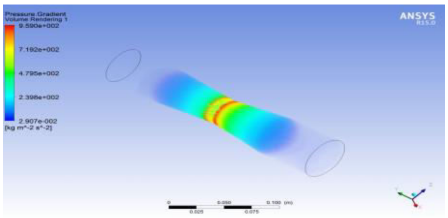
Emission percentages	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	PM (g/kWh)
Hyd-1	0.036	0.088	0.035	0.089

Hyd-2	0.032	0.096	0.031	0.097
Hyd-3	0.168	0.052	0.167	0.0523
Hyd-4	0.12	0.0368	0.11	0.0369
Hyd-5	0.112	0.035	0.111	0.0356
Hyd-6	0.104	0.0104	0.103	0.0105

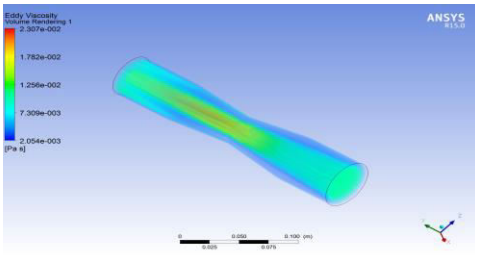
Table 4.4 shows that normal diesel engine hot shot emission

Emission percentages	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	PM (g/kWh)
Hyd-1	0.414	0.102	0.410	0.103
Hyd-2	3.068	1.104	2.068	0.105
Hyd-3	1.932	0.132	0.932	0.133
Hyd-4	1.38	0.4232	0.38	0.4233
Hyd-5	1.288	0.4048	0.288	04049
Hyd-6	1.196	0.1196	0.196	0.1197

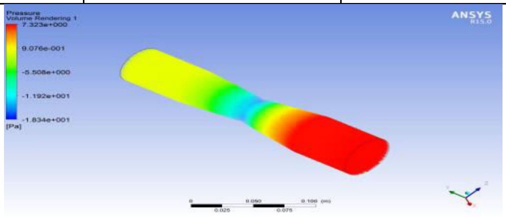
4.3 Analysis of catalytic filter:



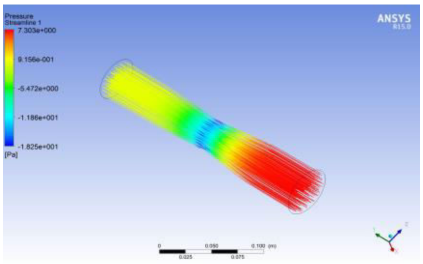
The figure 4.1 pressure gradient of the filter



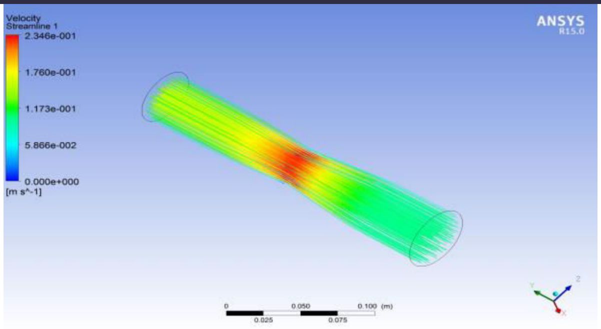
The fig 4.2 shows that velocity gradient



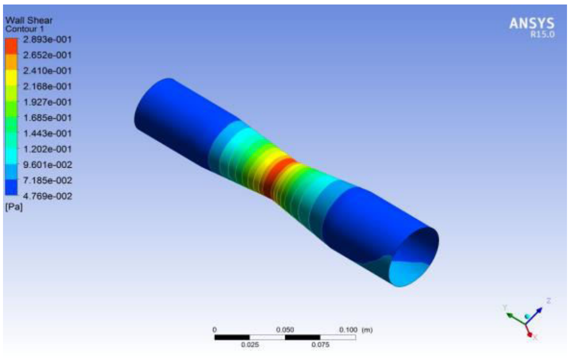
The figure 4.3 shows that pressure volume rendering of the filter



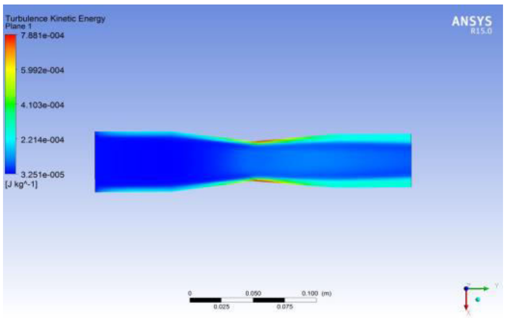
The fig 4.4 shows that Pressure streamline



The figure 4.5 shows that filter velocity steam line



The fig 4.6 shows that filter wall stressing model



The fig 4.9 shows that Turbulence kinetic energy

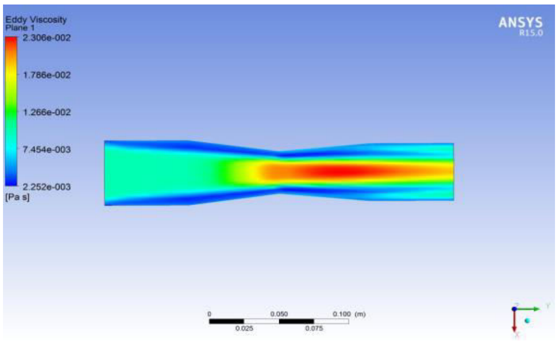
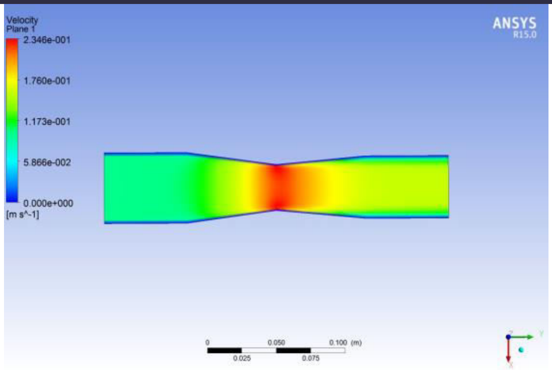
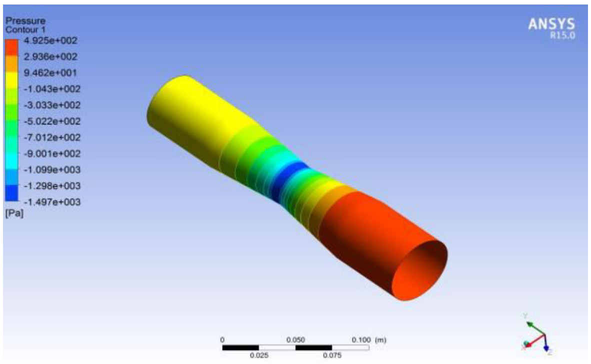


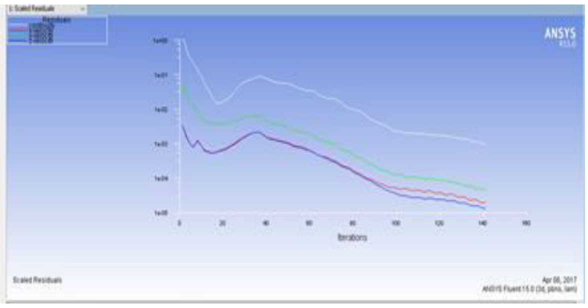
Fig 4.10 shows that Viscosity of the filter



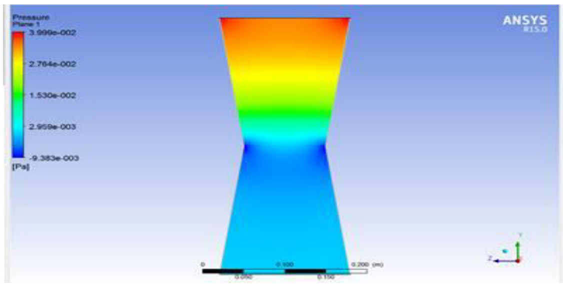
The fig 4.11 shows that velocity of the filter



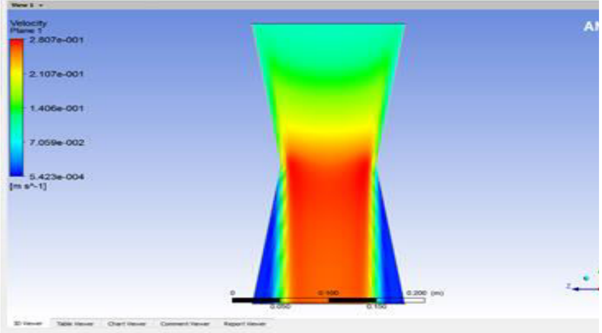
The fig 4.14 shows that pressure counter of the catalytic filter



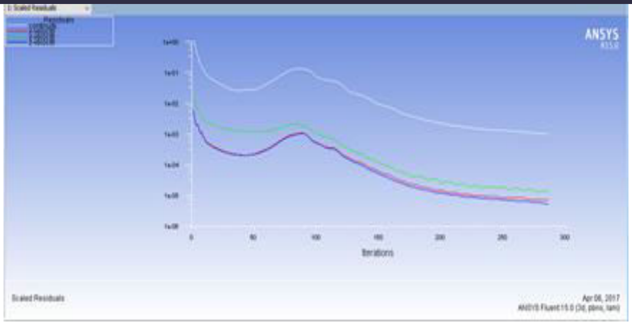
The graph 4.15 shows that one side passing through catalytic filter



The figure 4.16 Catalytic convert filter of the pressure plane



The figure 4.17 shows that velocity plane filter



The graph 4.18 shows that smoke passing through the filter in way

The table shows that the analysis of catalytic converts filter maximum and minimum values

Subject	Maximum deformation	Minimum deformation
Pressure gradient	9.590e+0.02	2.907e-0.02
Filter velocity	2.307e-0.02	2.054e-0.03
Pressure volume rendering	7.323e+000	-1.834e+0.01
Pressure steam line	7.303e+000	-1.825e+0.01
Velocity flow	2.346e-0.01	0.000e+0.000
Filter stress	2.893e-0.01	4.69e-0.02
Pressure vector	7.323e+000	-1.834e+001
Velocity vector	2.353e-0.01	0.000e+000
Viscosity	2.306e-0.02	2.252-0.03
Turbulent viscosity	7.881e-0.04	3.251e-0.05
Velocity plane filter	2.344e+000	0.00e+0.00
Pressure filter plane	7.312e+000	-1.834e+0.001
Filter Steam line	4.897e+0.02	-1.484e+0.03
Filter Velocity steam line	2.304e+000	0.000e+000

CONCLUSION

The catalytic convert filter characteristics of main pollutant emissions (CO, HC, PM, and NOx) from diesel engines and control technologies of these pollutant emissions with standards and regulations. Among these pollutant emission, CO and HC are emitted because of incomplete combustion and unburned fuel while NOx emissions are caused because of high combustion temperatures above 1,600 °C. As for PM emissions, the reasons of PM emissions are agglomeration of very small particles of partly burned fuel, partly burned lube oil, ash content of fuel oil and cylinder lube oil or sulfates and water. These pollutant emissions have harmful effects on environment and human health. Even though many applications have been implemented on diesel engines to prevent harmful effects of these pollutant emissions and to meet stringent emission regulations, only after treatment emission control systems are of the potential to eliminate the pollutant emissions from diesel exhaust gas. To control these pollutant emissions as desired is only possible with after treatment systems. Diesel exhaust after treatment systems include DOC, DPF, and SCR. These systems are the most requested components especially for heavy-duty diesel engines and usually a combination of DOC, DPF, and SCR has been respectively used for the simultaneous removal of main pollutant emissions from diesel engine exhaust.

The temperature of diesel exhaust gas has an important effect on reducing pollutant emissions. Besides catalyst type, space velocity of exhaust gas, and emission form are the other parameters affecting the efficiency. With the after treatment emission control systems, it is possible to reduce the damage of the pollutant emissions on air pollution, to meet emission standards and requirements, and to prevent the harmful effects of pollutant emissions on environment and human health. Due to these missions, emission control systems are utmost importance worldwide. For the complete destruction of polluting emissions from diesel engines, further studies and researches on the after treatment emission control systems should be intensified and continued.

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