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CFD investigation of temperature and pressure drop characteristics in a diesel particulate filter

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Abstract

Diesel Particulate filter (DPF) is an alternatively blocked device for filtering the Particulate emission from the compression ignition engines. Particulate flow field is very important one for soot oxidation and pressure drop in a DPF, because clogging particulate emission in the filter causes the back pressure and its affect the fuel economy and power of the engine. Vorticity near the dilation angle plays the important role on flow field of particulate emission so that to achieve the linear flow field, regenerate efficiency and life of filter the investigation were carried out by different dilation angles (25°, 45°, 65°) of DPF by using k-Ɛ turbulence model in Star CCM+.

Keywords: Diesel Particulate filter, Soot oxidation, Dilation angle, Pressure drop

1. INTRODUCTION

Diesel particulate filter device needs the laminar flow inside the filter for better flow distribution. Though number of researches involves in DPF, no work could be found on use of DPF design and CFD investigation in single cylinder compression ignition engine. The wall function and exhaust gas flow models taken from the following surveys.

Anastassios Stamatelos have developed a 3D model using FEM software the flow distribution among the different channels of the filter can easily predict the temperature field within the filter. Kazuhiro Yamamoto numerically developed the reaction rate of soot oxidation with the Platinum catalyst evaluated and developed Arrhenius equation for the first-order reaction found the pre-exponential factor and the activation energy 5.92 ×109 1/s, 184 kJ/mol respectively, when the temperature of filter reached 800K the soot saturated regeneration begins.
Law has theoretically analysed the regeneration characteristics and activation energy for soot oxidation model. Mizutani concluded low gas flow rate and high oxygen concentration bring a high maximum temperature. Psarianos experimentally studied the soot loading, it affects the permeability of soot in the filter layer, the results (ρk)p (soot layer density times permeability) for the specific engine and filter combination lies in the range from 3.5×10-12 to 1.15×10-11 kg/m, both for a cordierite and an Silicon Carbide filter.

Vivek W was conducted engine performance under 100% engine load at constant engine speed for different aspect ratio of filter, brake thermal efficiency and %smoke density were calculated, the smoke density decreases with increase in aspect ratio. Minimum smoke density observed for 0.9 aspect ratio. Performance of DPF was better at higher aspect ratio 0.9 smoke density is reduces about 1%.Maximum filtration efficiency is observed about 82% for 0.9 aspect ratio, engine Brake thermal efficiency reduces 25% to 23% due to increase in back pressure. Zhong-chang experimentally verified soot loading 7g/L is safe life for DPF regeneration.

2. METHODOLOGY

Modeling of DPF using Pro/E Wild fire is created and exports the solid model to Star-CCM+ and generates computational grid then analysing the process for the specified initial and boundary condition.The height of each channel is 1.5 mm. The filter plate thickness, which is connected to the channel, is 0.4 mm and its porosity and mean pore size, are 0.45 and 10 μm respectively.

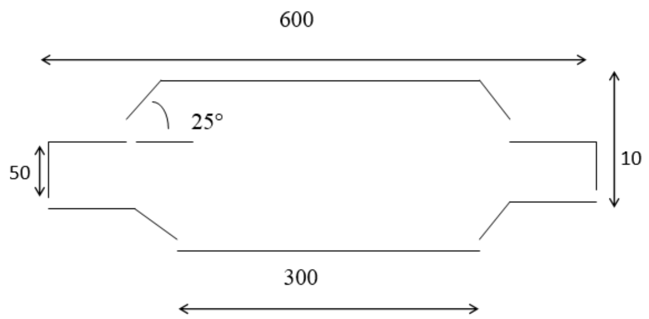

Figure.1.Outline structure of DPF

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Table.1.Mesh properties for different dilation angle of DPF model

Dilation angle	**25º Dilation angle**	**45º Dilation angle**	**65º Dilation angle**
Mesh Model	Polyhedral	Polyhedral	Polyhedral
Base Size	0.0021	0.0029	0.030
Total number of cells	201403	500591	580405

The method which is used for wall treatment in Star-CCM+ is "All y+ Wall treatment'' which is a hybrid treatment for both high and low y+.

Table.2.Under relaxation factors

Parameter	Under relaxation factor
Velocity	0.7
Pressure	0.3
K- ε turbulence viscosity	0.8

3. RESULTS AND DISCUSSIONS

Velocity field:

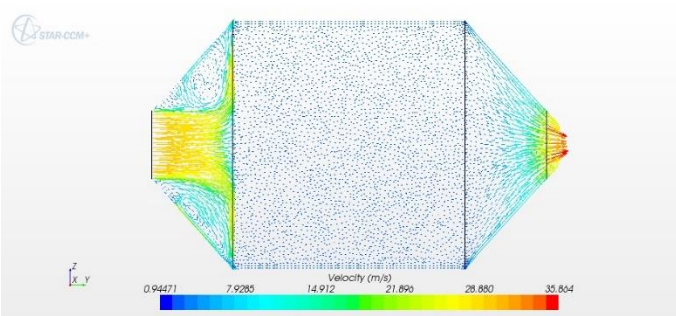

Figure.2.Velocity distribution for the 45º Dilation angle, dirty filter

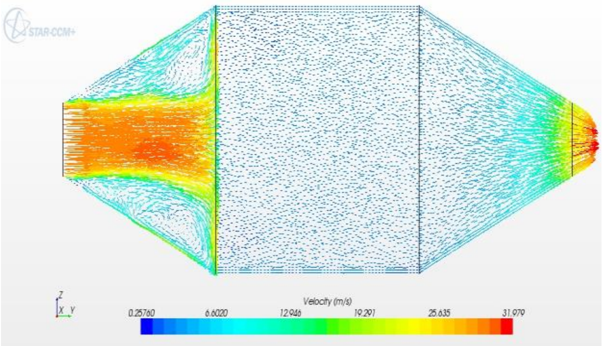

Figure.3.Velocity distribution for the 65ºDilation angle, dirty filter

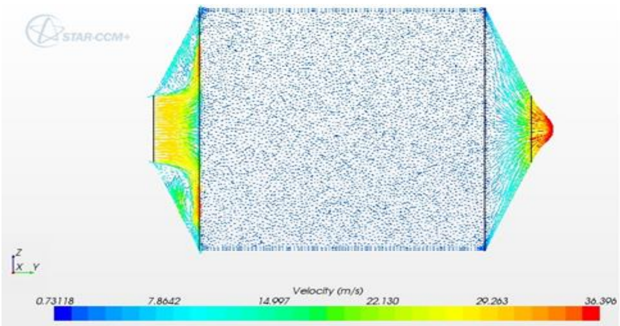

Figure.4.Velocity distribution for the 25º Dilation angle, dirty filter

Vorticity influence on 45° and 65° is very severe to the flow field but nearly uniform flow inside the filter achieved by 25° dilation angle because of influence of vorticity near the filter is very small.

Pressure field:

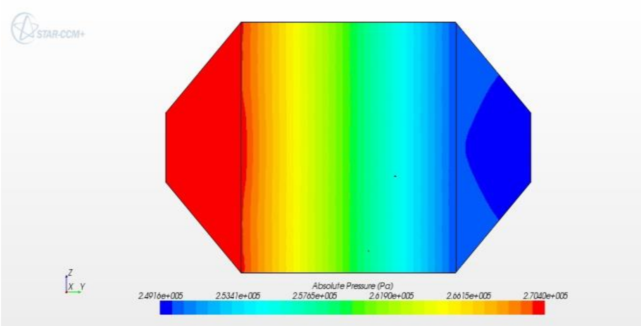

Figure.5.Pressure distribution for the 45° Dilation angle, dirty filter (ΔP=21 kpa)

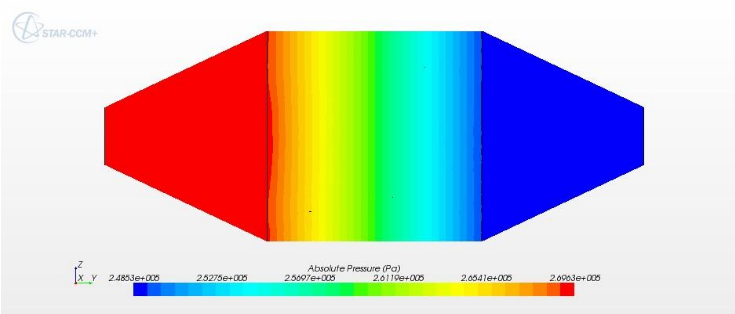

Figure.6.Pressure distribution for the 65° Dilation angle, dirty filter (ΔP= 21 kpa)

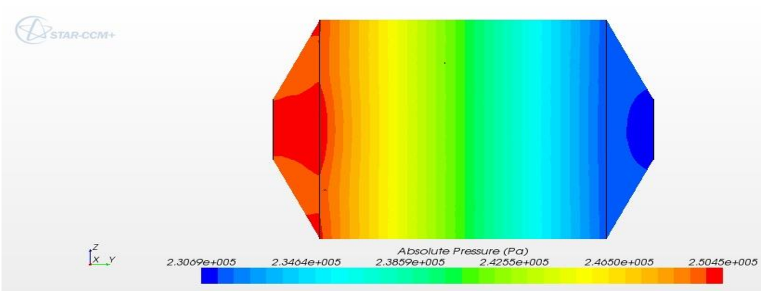

Figure.7.Pressure distribution for the 25° Dilation angle, dirty filter (ΔP=19 kpa)

Table.3.Pressure drop factor for simulation

	Soot amount (gr)	25° Dilation angle ΔP Sim (kpa)	45° Dilation angle ΔP Sim (kpa)	65° Dilation angle ΔP Sim (kpa)
Clean filter	0.6	4	3.7	3.5
Semi dirty filter	4	11	14	15
Dirty filter	7	19	21	23

Increase in Pressure drop due to soot load for 25° Dilation angle is permissible range whereas others increases the pressure drop can cause the back pressure and affects the engine performance.

Temperature Distribution Profile:

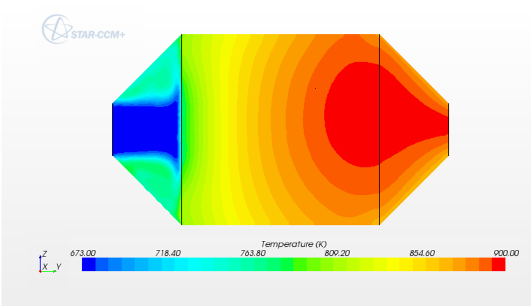

Figure.8.45° Dilation angle temperature distribution profile during regeneration

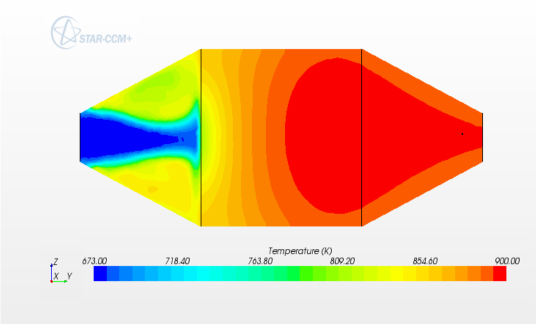

Figure.9.65° Dilation angle temperature distribution profile during regeneration

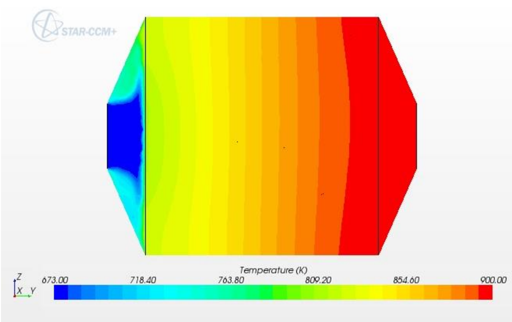

Figure.10.25° Dilation angle temperature distribution profile during regeneration

When the exhaust gas temperature has reached 673K filter temperature was increased at the time soot oxidation promoted and further temperature of filter substrate increased up to 900K soot was oxidised completely at the end of the DPF.

The uneven temperature distribution profile was observed in 45° Dilation angle and 65° Dilation angle shows in figures because of non-uniformity of soot in the DPF, but 25° Dilation angle even temperature distribution profile was observed compared to others due to uniformity flow of soot.

Validation: In the validation of a pressure drop and soot oxidation temperature analysis of DPF computed data at dirty filter is going to compare with experimental data.

Table.4.Validation of pressure drop and Temperature

Parameters	Experimental	Star- CCM+	Percentage Error
Pressure Drop (Kpa)	20.75	19	8.433
Temperature (K)	880	900	2.3

The numerical simulation values obtained in the present study are compared with the available experimental results of Zhong-chang et al., It is observed that the pressure drop and regeneration temperature for model is 19Kpa and 900K whereas in experimental it is 20.75 Kpa and 880 K respectively. The results are found to be in close agreement.

4. CONCLUSION

The flow field distribution inside the filter is laminar flow for 25° dilation angle compared to 45°, 65° dilation angle because of less vorticity influence. Soot loading 7g/L is safe regeneration for DPF having 25° dilation angle and temperature and pressure drop is permissible range it leads to good life of DPF.

REFERENCES

Anastassios Stamatelos and George Pontikakis, 3-D Catalytic Regeneration Modeling of SiC Diesel Particulate Filters, SAE paper, 2002-01-1017.

Kazuhiro Yamamoto, Kazuki Yamauchi, Numerical simulation of continuously regenerating diesel particulate filter, Proceedings of the Combustion Institute, 2012, 1-8.

Law MC, Clarke A and Garner CP, The effects of soot properties on the regeneration behavior of wall-flow diesel particulate filters, Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering volume, 218, 2004, 1513-1524.

Mizutani T, Watanabe Y, Yuuki K, Hashimoto S and Hamanaka T, Soot Regeneration Model for SiC-DPF System Design, SAE paper 2004-01-0159.

Versteeg H, Malalasekera W, An introduction to computational fluid dynamic, the finite volume method, Pearson publication, England, 2007.

Vivek W Khond and Deshmukh MM, Design and Performance Investigation of Diesel Particulate Filter with Variable Aspect Ratio, International journal of industrial engineering and technology, 3, 2011,173-177.

Zhong-chang, Wang Dan, Han Yong-qiang, Zhang Jian-rui, and LIU Jiang-wei, Experimental Studies on Pressure Drop Performance and Regeneration Safety of Diesel Particulate Filter, International Conference on Electric Information and Control Engineering (ICEICE), 2011, 2175 – 2178.