Numerical simulation of the effect of material catalytic converter on gas emission

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Abstract. The disposal of gas emission from vehicle is the biggest contributor to the environmental pollution which generates most carbon monoxide, hydrocarbon, and lead (Pb=Plumbum). Those substance particulates are pollutants and harmful for both the environment and human life. One of the innovations that can reduce the pollutive particulates is to reduce CO gas by assembling a catalytic converter are displayed. In order to find out the effect of catalytic converter absorption toward (CO) gas particulate, varied with various materials in an environmentally friendly catalytic converter, a simulation using fluent software is carried out. From the simulation, it is seen a significant thermal condition and CO mass fraction absorption from various different materials, by applying mass fraction of CO=0.04;N_2=0.8796; and O_2=0.12, the decrease of high mass fraction (decrease of CO=0.004 mass fraction) occurs at the channel centre area due to the mass fraction of various materials that moves away from the center with a longer rest time (high conversion) at the surrounding channel.

1 Introduction

Fossil fuels used by motor vehicles are the largest contributor to air pollution, especially NO_2 and CO which amount more than 50% in free air. It can cause negative effects to human health and to the environment. Research on the effects of air pollution waves has been investigated by Jing Huang et, al. [1]. With the air pollution index (API)> 100, the effects of air pollution waves for 2 or more consecutive days were evaluated by counting the number of life lost (YLL) due to accidental, cardiovascular and respiratory deaths in the city of Tianjin, China, from year 2006 to 2011. The results of this study indicate a considerable long-term effect due to high levels of air pollution for days.

One of the technologies that can be used to reduce CO emissions is the Catalytic Converter installed in the gas emission drainage system. Research on catalytic converter has been done, as did by V. K. Chakravathy et. al. [2]. In the study, the effects of flow uniformity during the transient cold start process of the catalytic converter were studied using a multi-channel model. The results of this study indicate that the uniformity of flow that occurs within the monolith is caused by the recirculation that occurs in the inlet zone. This causes the different characteristics of ignition between the channels, especially in sewers that have lower temperatures. Junhu Zhou et. al. using catalyst to implement micro-combustor that has low stability [3]. Quartz glass material, ceramic alumina, and copper are compared to determine the performance of the micro-combustor. By using these three variations of material, the combustion chamber has a high stability and can work up to an extreme equivalence ratio. However, in quartz glass and ceramic alumina materials, the combustion chamber works at a high temperature of about 1058 ºK, while for catalytic with quartz glass material and 728 ºK for catalytic with ceramic alumina material. While the catalytic with copper material has a lower temperature distribution.

This study aims to investigate the effect of the different catalytic converter materials, which is Cu, Ni, and Al on exhaust emissions and to know the physical flow of the fluid through the catalytic converter by using computational method (CFD)). With this simulation is expected to be used as a reference to improve the exhaust system to produce environmentally friendly exhaust gas.

2 Research methods

Catalytic converter is a tool used as a controller on exhaust emissions that are placed after exhaust manifold before the vehicle exhaust system or before entering on the muffler. The effect of material from catalytic converter (Cu, Ni, and Al) on velocity contour, temperature and mass fraction of carbon monoxide (CO) was analyzed using CFD method. The geometry of the catalytic converter in this study is shown in Figure 1.

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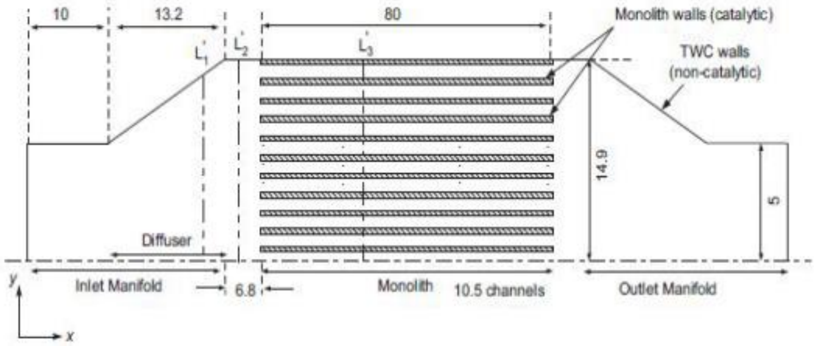

Fig. 1. Geometry of catalytic converter

The fluid flow velocity used in this research is 6.3 m / s, while the particulate used is carbon monoxide (CO) with the inlet temperature condition of 720ºK at 1 atm pressure. Where the density of air is 1.255 kg/m^3 and the viscosity of air is 1.87x10^{-5} Kg/m-s. Fluent software is used to solve the equations that exist in this study. Which Fluent uses computational methods based on cell-centered, unstructured finite volume descritization, and SIMPLE segregate solution procedure [4]. All computations in this study were calculated using a second order upwind scheme to complete the convective terms and central different for diffusive terms. While the grid used in this study is a grid with type Quad-Map with the number of grids of 26981 nodes, as shown in figure 2.

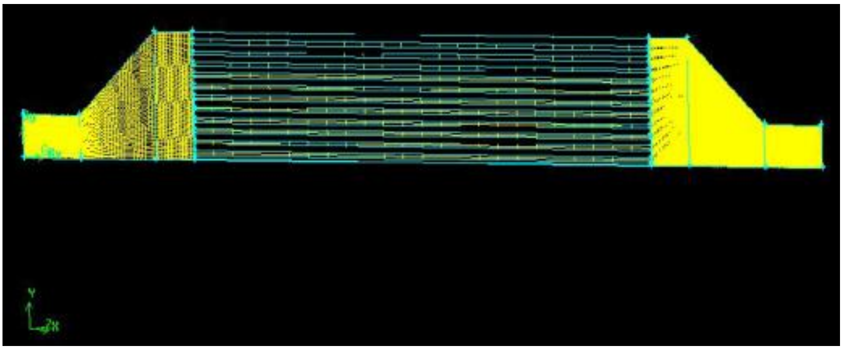

Fig. 2. Meshing for catalytic coverter

3 Result and discussion

3.1 Numerical validation

The validation process is used to determine whether the results we get from the research is correct or not. In validating, the data we obtain is necessary to compare with previous studies. In this case, the results obtained from this study were compared with the results obtained from research conducted by Gaurav et. al.[5]. Table 1 shows the results of comparison of velocity magnitude values performed by Gaurav et. al with present study. Where in the table shows that the value of velocity magnitude obtained from the present study amounted to 1.20x10^1, whereas in the previous study obtained velocity magnitude 1,24x10^1. It shows that the current study has a smaller velocity magnitude value compared to the previous researchers with a difference of about 3.22%. So from these results indicate that the simulation is feasible for further use.

Table 1. Comparison of experiment result value

No.	Study	Velocity Magnitude
1	Gaurav Arawal et.al. (2012)	1,24x10^1
2	Present Study	1.20x10^1

3.2 Contour speed

By varying the forming material of converter catalysts, the results of velocity magnitude measurements in this study have the same relative pattern contours in each material variation (Cu, Ni, and Al) as shown in figure 3. The figure shows that a large recirculation is formed in the diffuser inlet characterized by a swirling flow at the top and bottom, due to the suddent expansion (sudden area dilatation). This causes the flow to be non-uniform. The transfersal component is lower than the axial velocity component at center, so it indicates the presence of fluid that moves or shifts toward the surroundings (top and bottom). Pressure drop also occurs in the channel catalytic converter due to factions along the channel. With the inlet speed on each channel that has narrow gaps, the flow rate becomes high and produces high friction. The effect of the friction will make the flow across each channel be uniform.

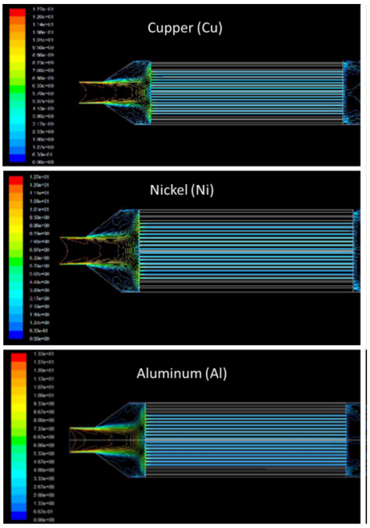

Fig. 3. Comparison of contur velocity magnitude (m/s)

3.3 Static temperature contour

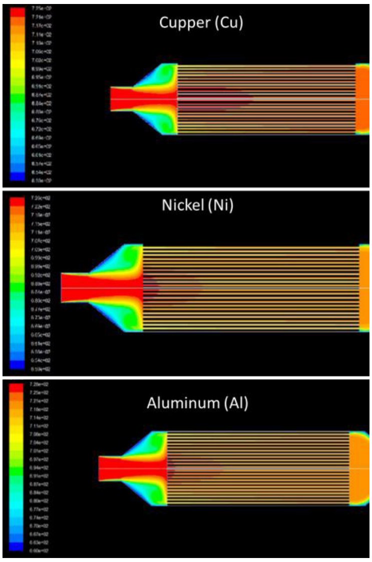

Fig. 4. Comparison of temperature contour (K)

The result of static temperature contour analysis using numerical simulation method with Cu, Ni, and Al material variation on catalytic converter, shown in figure 4. In the figure, the temperature around the channel is lower than the channel's middle region, this is due to the heat loss that occurs in the surrounding. From the comparison of the three materials, when viewed from the blue to red color index in which the blue color indicates a low temperature and red color indicates a high temperature value. From the three materials, catalytic with aluminum material has a high temperature area large compared to the others. This is indicated by areas that have a greater red color in catalytic with aluminum material than with catalytic with copper and nickel material.

3.4 Mass fraction (CO) contour

With particulate carbon monoxide (CO), mass fraction was simulated and analyzed in this study. The results of the analysis are shown in Figure 5, the figure shows the mass friction contour of CO with the catalytic converter material variation. The results show that the CO mass fraction accumulates in the diffuser before it enters the catalytic channel and causes the CO massive fraction to be very large in the area. When the CO mass passes through the catalytic channel, the mass fraction decreases gradually to the peripheral channel or outlet. Generally from the comparison of Cu, Ni, and Al materials shown in figure 5, catalytic converters with aluminum material can absorb more CO than other materials. This is indicated by a low fraction region or a larger yellow area on the image.

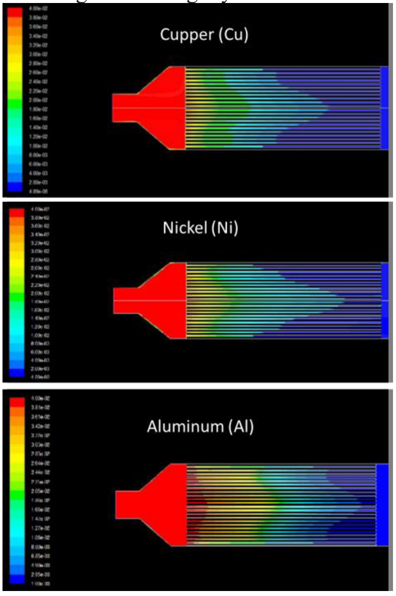

Fig. 5. Comparison of mass fractions CO contour

4 Conclusions

From the results of numerical simulations about the effect of different catalytic converter material on exhaust emissions, it can be concluded that:

1. Large recirculation is formed in the diffuser inlet shown by the swirling flow at the top and bottom due to the suddent expansion.
2. The contour of the temperature around the channel is lower than the middle of the channel.
3. From the three materials, Aluminum (Al) absorbs more CO than others.

With this simulation is expected to be used as a reference to improve the exhaust system to produce environmentally friendly exhaust gas.

References

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