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A study on emission reduction at cold start using an electrically heated three-way catalyst in series hybrid passenger vehicles

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With the worldwide strengthening of environmental regulations for automobiles in recent years, the importance of reducing autoexhaust emissions at cold start is increasing than ever before. Regarding the tailpipe out THC (Total Hydrocarbon) emission from current gasoline vehicles, it is considered that 65–80% of the total emission in transient mode tests has been discharged in a short time from the cold start to reaching light-off temperature of TWCs (Three-way Catalysts). Though HEVs are becoming more popular in Japan, under the accelerated movement towards the electrification of powertrain systems with the intensifying discussion on carbon neutrality, emission reduction at the cold start is still a common significant challenge on the whole gasoline engine vehicles including HEVs. An EHC (electrically heated catalyst), which enables earlier temperature rising and activation of catalysts, is one of the effevtive solutions, hence is expected to be in practical use in the future. In the development of HEVs, additionally, MBD (Model Based Development) is promoted to reduce the increasing development cost along with the increasingly complex powertrain systems. Therefore focusing on a SHEV (Series HEV) which is expected further expantion of market share, we have invested much effort in building a numerical calculation model of a TWC that performs the most important role in the exhaust purification system. In this study, it was aimed to predict how far the cold start emissions can be reduced while minimizing excess fuel consumption, through simulations using the TWC model as EHC.

Firstly, vehicle tests on WLTC (Worldwide Light-duty Test Cycle) mode using TWC/EHC (TWC coated on a silicon carbide EHC substrate) were conducted under multiple EHC control conditions to investigate its effectiveness. As the result, the higher the power supply, the more CO and THC are purified, indicating that the emissions during 0-100 seconds can be reduced to less than half. However, the slope of the growth is large up to 100 kJ of power supply, but tends to converge above that level as shown in Fig. 1. In addition, it was suggested that a longer preheating time is more advantageous in reducing emissions.

Secondly, simulations using the TWC model developed so far as EHC were performed, and the results were compared with the experimental results. Although the timing of the onset of temperature rise was earlier and the rate of rise appeared somewhat greater in the calculation, the TWC/EHC model was generally able to reproduce the temperature rising behavior in the experiment. It was also revealed that the model can predict CO and THC conversions with an error margin within ±10% for the experimental results. Therefore, this TWC/EHC model was verified to have high prediction accuracy even in simulations under various EHC control conditions within a realistic range.

Finally, the optimization of the EHC control conditions, and the optimization of the volume and arrangement of the heating zone were studied by parametric study on the model, for the emission reduction during cold start. It was found that keeping the catalyst as warm as possible by the time of initial engine start is a prerequisite for efficient EHC use. The highest effect was expected when the heating zone was limited to a certain length of the inlet side to accelerate the temperature rising. It was suggested that by combining the optimization of EHC control conditions with that of the heating zone, significant reductions in CO and THC emissions of 60% and 50% or more can be achieved, respectively, while keeping the trade-off excess fuel consumption to approximately 1.0%. (Fig. 2)

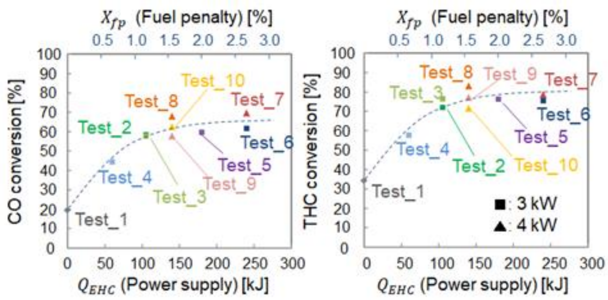

Fig. 1 Comparisons of CO and THC conversions in WLTC mode during 0–100 s among the total of 10 EHC control patterns

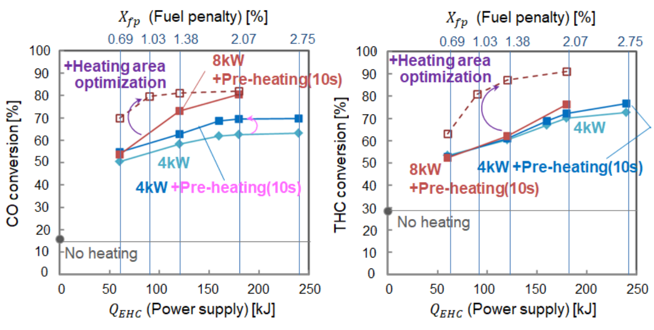

Fig. 2 Summary of simulation results with EHC heating for CO and THC conversions in WLTC mode at 0–100 s

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