

Experimental Investigation of Factors Affecting Odors Generating from Mobile AC Systems Equipped with Idling-Time Reduction Systems

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ABSTRACT

In last 10 years or so, a number of OEMs are designing vehicles with start-stop function to save energy and to reduce pollution. For these systems, the situations in which air-conditioning systems are used have been changing with a significant increase in adoption of idle-time reduction systems (no idling-system). Blower fan remains operating at idle condition while compressor stops in most cases for these systems. In this case, the air temperature at the vent outlets increases. The increase in the air temperature under range of thermal boundary conditions around the evaporator causes a concern of odor to occur. This paper describes and explains experimental studies on changes in heat and humidity at the air outlets according to the switching operation of compressor and root cause analyses of odor coming from air-conditioning system for vehicles with start-stop function.

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1. INTRODUCTION

Improving passengers comfort is one of the important functions of air-conditioning systems. One of the main factors which degrade the comfort is "generation of the odor when using an air-conditioning system." CK (CalsonicKansei) has analyzed odor-generating mechanisms to suppress various kinds of odor as shown in [Figure 1](#). At the same time necessary countermeasures are taken to prevent odor generation from the HVAC system.

1. Adhesion - odor from evaporator with ventilating air
2. Dusty odor just after turning on an air conditioning system (compressor-on)
3. Burnt - odor which generates when an evaporator partly gets frozen
4. Stuffy - odor just after turning off a compressor.

Vehicles with a start-stop system, which can automatically shut down and restart the engine to reduce engine-idling time, thereby, reducing fuel consumption and emissions have been increasing in the market lately. Air-conditioning systems operating in for start-stop systems operates under conditions that have not been investigated in details. To solve issues caused by the above change, CK has analyzed changes in usage environment of the air-conditioning systems caused by adding the above idling-time reduction systems and its impacts to odor generation.

2. CHANGES IN AC SYSTEM USAGE BY ADDING IDLE TIME REDUCTION SYSTEM

As discussed in the previous section, different types of odors generate from an air-conditioning system:

- Outlet temperature of evaporator
- State of condensed moisture from airstream on evaporator surface

CK has conducted controlled tests for a range of evaporator outlet temperatures, thereby preventing freezing & increase in evaporator surface temperature, and suppressing odor. Vehicles equipped with Idling-time reduction systems have been increasing in the market lately, aiming for saving power, and thus, reducing CO₂ emission. Compressors for air-conditioning systems in such systems stop at the same time the engines stop. This implies that one can predict an **environment in which the outlet temperature of evaporator increases**. (See the Area A in [Figure 1](#))

3. VEHICLE ODOR-GENERATING TEST

As stated in the previous section, we focused on the area in which the outlet temperature increases, and measured the temperature during idle stop and checked odors generated during this timeframe. As shown in [Figure 2](#), the outlet temperature of an evaporator starts to

decrease when the compressor is turned on. And based on an idle stop, the compressor turns off and the evaporator outlet temperature starts to increase. After that, we confirmed that an area existed (Area B: Temperature-stable area) after the temperature starts to increase at the time the vehicle stops idling. At this point a sour smell generates just before the temperature starts to increase.

4. STUDY ON CONDITIONS GENERATING ODOR

4.1 Impacts of Idling-Time Reduction Functions

Based on the results from vehicle odor evaluation, one can predict the generation of the sour smell in the temperature stable area (Area B in [Figure 2](#)), just prior to an increase in the evaporator outlet temperature. This phenomenon can be explained as follows: Moisture from airstream condenses over the evaporator surface that is below the dew point of the inlet air. During this idle stop, the compressor is off and the condensed water starts to evaporate when the evaporator surface temperature increases (See area B in [Fig 2](#)). At this time, heat is taken from the evaporator and the evaporator temperature becomes almost constant for a short duration. This is the time when a sour smell is generated. Based on the results of a vehicle test, we confirmed the odor generated at the time the condensed water had completely evaporated which was just before the temperature started to increase form temperature-stable area. Based on the above, one can conclude that it takes a finite time to evaporate the condensed water completely. Based on this we can predict the time at which the odor will be generated after the compressor has been turned off due to idle stop.

4.2 Creating a Map for Estimating Odor-Generating Conditions

As stated in the previous section, the odor in question generates both when moisture from airstream is condensed and after the condensed water has completely evaporated. Considering the above, we focused on the temperature (dry-bulb temperature) and humidity (relative humidity) of the air at the inlet of the evaporator and the conditions under which moisture from airstream can condense.

1. Formation of Condensate from Air-stream and its evaporation: Moisture from airstream is condensed over the outside of the evaporator plate that operates below the dew point of the inlet air. At the same time the condensed water evaporates only when the outlet temperature of the evaporator increases the wet-bulb temperature for intake-air.
2. Time to evaporate condensed water: Applying the intake-air load in temperature-stable area, it takes a while to evaporate condensed water at low-temperature and high-humidity; and does not take much time to evaporate at high-temperature and low-humidity. We predict that it is possible to express "the degree of ease to get dry" with temperature difference of the dry-bulb and wet-bulb temperature of an evaporator (ΔT) under the operating conditions.

For large magnitudes of ΔT , the dry-and wet-bulb temperatures are lower. This becomes the condition of the low-humidity as stated above, so this causes the condensed water to evaporate quickly. In

contrast, for smaller values of ΔT humidity level is high. This means the condensed water will evaporate slowly. Accordingly, we believe that the magnitude of ΔT has an impact on the time it takes for the water to evaporator and how often the odor is generated. [Figure 3](#) is a map for estimating odor-generating conditions under different operating condition (temperature and humidity) of the intake air.

Area C (Estimated area in which odor generates) in [Figure 3](#) means that the odor is supposed to generate within this area under the condition of temperature and humidity of intake-air. This area is defined by Line A and B explained below:

Line A: A line on which a dew-point temperature under intake-air load becomes the same as evaporator controlling temperature (Dew point=EVAP control temperature)

Line B: A line on which a wet-bulb temperature under intake-air load becomes the same as the one at which an idle-stop function is cancelled (Wet-bulb temperature=Stopping idle function cancelling temperature)

This means that no condensed water is formed when the dew-point temperature is Line A or less as well as no condensed water evaporated when the wet-bulb temperature is Line B or over, which means these conditions does not fill the necessary conditions generating odor.

In other words, we believe that we could suppress the odor generation by setting the evaporator controlling temperature (Line A) to higher, and the temperature at which a stopping-idling function is cancelled (Line B) to lower, thereby, reducing the range in which evaporator outlet temperature is used and lowering the percentage of appearance of temperature-stable area.

5. ODOR REPRODUCTION BENCH TEST

The test was conducted by accurately reproducing vehicle testing conditions which allowed us to ensure quantitative evaluation in verifying the validity of the estimated odor generation areas outlined in [Figure 3](#).

5.1 Odor Reproduction Bench Evaluation Test Methods

An A/C system was set up in a thermostatic room as shown in [Figure 4](#) to produce vehicle's A/C system operating conditions, and then human odor panel testing was performed. A panelist was positioned 30cm away from the A/C outlets, assuming a driver's actual seating position (refer to [Figure 4](#)).

5.2 Odor Reproduction Bench Test Evaluation Results

As a result of the bench test, it was confirmed that a sour smell previously found in the vehicle test, was generated in the stable temperature area as shown in [Figure 5](#).

In regard to the effects from ΔT , when ΔT reaches approx. 10°C and more, the condensed water of the evaporator surface dried earlier.

Due to this, the odor was generated in a short time after A/C was turned off. That is to say, when applying the results to a vehicle, it is