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Development of a temperature controlled weathering test box to evaluate the life cycle behaviour of interior automotive components

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Abstract: It is the desire of every motorist to drive an exquisite vehicle, so it is very crucial for players in the automotive industry to keep on improving the quality of vehicles. While the interior components of a vehicle are the most critical components to the overall durability and comfort of a vehicle, it is important to guarantee the quality of these components. Vehicle interior components are usually made of plastic, leather, fabric and painted components which can all be prone to quick ageing. Fading, cracking and distortion are rife in vehicle interior components, and these effects are caused by natural factors such as radiation, moisture and extreme temperature. This phenomenon is known as "weathering". Tireless work has been done over the decades to carry out weathering tests on automotive components in order to address critical areas during the design process of the components. This paper explores one method of carrying out weathering tests on automotive dashboards in which a metallic testing box is used to simulate the conditions inside a vehicle. The main concern is that the temperature inside the test box can go above the necessary testing range which causes test samples to be destroyed before sufficient data is collected. A temperature control system was developed and installed to monitor the temperature inside the box. Weathering tests are being carried out in extremely harsh environments; therefore both the weathering test box and the temperature control system have to be robust. A solar-powered programmable logic controller (PLC), which has the ability to withstand harsh conditions, was used to monitor and control the system.

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1. INTRODUCTION

Weathering has been a critical subject for several decades especially to the automotive industry. Several methods for carrying out weathering tests are being used by automotive companies as well as by companies specialising in material testing. This paper focuses on the response of automotive dashboards to global radiation. It is common for motorists to park their vehicles in the sun for prolonged periods of time. The effect of global radiation on interior automotive components is often overlooked but it yields raging results over the service period of a vehicle. Weathering tests can be carried out by exposing test samples to natural conditions or by simulating natural conditions in the laboratory (Atlas Materials Testing Solutions 2001:5). When natural conditions are simulated in the laboratory, it is called "accelerated weathering". The advantage of accelerated weathering is that the test results are obtained quickly. However, accelerated weathering cannot simulate the global radiation spectrum in total (Atlas Materials Testing Solutions 2001:6). Accelerated weathering is compatible with time-to-market constraints; it provides test data quick enough to allow changes in the product design process. However, it does not accurately reproduce failure modes seen in real life (Haillant 2011).

In this paper, a low cost weathering testing method is explored. A local automotive company is using two methods to test interior vehicle components for weathering. The first method is to park a vehicle in the sun such that the sun shines through the windshield and degrades the interior components while test data is continuously taken. The biggest shortfall of this method is that the vehicle will be of little value at the end of the testing period which makes this method costly.

To remedy the concern of using cars to carry out weathering tests, the local automotive manufacturer has adopted the use of testing boxes. The size of a testing box is such that it can accommodate the dashboard of a passenger vehicle. The dashboard is put into the testing box and it gets exposed to maximum global radiation which shines through a glass cover mounted at a convenient angle. These tests are being carried out in areas with extreme levels of global radiation, temperature and moisture. Atlas material testing solutions also uses a similar technique but with integrated azimuth tracking on the box to achieve maximum solar irradiance. Atlas also uses fixed exposure racks for testing various components (Atlas Materials Testing Solutions 2001:34). In this paper a PLC was chosen as the most suitable type of controller for this application.

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A PLC is an industrial type of controller and it has the ability to withstand very harsh environmental conditions such as temperature and humidity (Fernandez, Fernandez & Poza-Saura 2010). Power supply for the PLC was mainly a solar powered battery system.

The use of solar energy in recent years has made standalone solar-powered systems advantageous due to the reduction in the cost of photovoltaic (PV) modules compared to fossil fuels (Peterson 2012).
The use of the testing box has the biggest disadvantage of failing to perfectly simulate the conditions inside a real car. Because the box is approximately perfectly sealed to allow heat to accumulate inside, the temperature inside the box often gets too high and the test samples get destroyed before useful data has been collected. The task of the researcher was to design a temperature monitoring system whose installation does not compromise the functioning of the box.

2. PROBLEM DESCRIPTION

2.1 Layout of the test box

Fig.1 below depicts the unmodified testing box, i.e., with no temperature control system installed. The glass on top is mounted at an angle of 30º and the box is always facing to the equator during tests so as to allow maximum radiation to be trapped all day. The box, which is approximately sealed to allow accumulation of radiation and to keep contaminants out, is made of galvanized sheet steel and is painted black inside.

Fig. 1: Layout of the testing box

The box was modified to include 3 main features: the inlet duct, the perforated plate at the bottom (hereinafter called the diffusion plate) and the outlet chimney. A properly sized (calculation to follow) temperature controlled fan was installed inside the inlet duct. Immediately after the fan, an electrically actuated damper was installed to keep the duct closed when no cooling is taking place. At the point where the outlet chimney is attached to the box, a back draught shutter was installed to ensure that the outlet chimney keeps closed when no cooling is taking place. In this manner, the box is kept closed and the required amount of heat can accumulate. Another feature of the design is that the fan is installed outside the box and hence it does not experience the excessive temperatures inside the box.

2.2 The heating effect inside the testing box

Radiant energy from the sun travels as waves in form of pockets of energy called photons according to (1) below (Holman 2002: 443).

$$E = hf \tag{1}$$

Where E = photon energy, $h = 6.625 * 10^{-34} J.s$ is the Plank's constant and f is the frequency in Hertz (Hz).

Equation 1 can be rewritten as:

$$E = (hc)/\lambda \tag{2}$$

Where $c = 3.0 * 10^8 m/s$ is the speed of light in a vacuum and λ is the wavelength in meters. From (2), it can be seen that the photon energy is inversely proportional to the wavelength. Shorter wavelengths are therefore associated with more energy than longer wavelengths.

The solar radiation that reaches the earth's surface consists of photons with wavelength between 2.95µm and 3µm (Holman 2002: 375). "Ordinary glass can transmit radiation readily at wavelengths below 2 µm, meaning that it will transmit most of the solar radiation incident upon it. However, this same glass is opaque to long-wavelength radiation above 4µm (Holman 2002: 375). Consequently, the glass will not permit most of the trapped radiant energy to escape back into the atmosphere thereby creating a heating effect inside the box. This concept is known as the greenhouse effect.

The testing box works on the greenhouse effect as briefly explained above. Temperatures are allowed to go up to 110ºC while temperature data is constantly logged for purposes of evaluating the life cycle behaviour of automotive dashboards. However, if the temperature is uncontrolled the heat inside the box becomes excessive and the test samples get destroyed before meaningful data has been collected.

Previous attempts to ventilate the box have proven to be problematic. The major concern was that it is required to modify the design of the box as careful as possible so as to allow the box to remain approximately sealed otherwise no sufficient heat accumulates and the purpose of the tests will be defeated. The problem was solved by introducing external airflow ducts which are kept closed by electrically actuated dampers. The whole system was designed to function on a solar-powered battery system to make it a complete standalone. Fig.2 below shows a fan which melted while installed inside the box to attempt to ventilate the box during excessive heating.

Fig. 2: Excessive heating inside the box

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