2006-2069: INTRODUCING MATERIALS ENGINEERING CONCEPTS IN A HIGH SCHOOL AUTOMOTIVE TECHNOLOGY CLASS

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Introducing Materials Engineering Concepts
In a High School Automotive Technology Class

Introduction

In an effort to motivate high school students to consider future career opportunities in engineering and to appreciate the importance of engineering technology in creating a pollution-free environment, an educational outreach program was developed as a partnership between a university. The program is designed to create awareness among students about the environment, the potentials hazards it could face from humankind and the possible methods to alleviate the problem.

The idea has been executed in a high school automotive technology class where students work hands-on with automotive engines. One of the experiments was to measure the exhaust emissions. Automotive exhaust has been of great concern in recent years due to its dramatic impact on the environment. Much research has been done on exhaust emission systems in order to control the levels of the potentially toxic components of exhaust gases. A major breakthrough in the exhaust emission systems was the invention of catalytic pollution control system. Commercial applications of catalytic pollution control from internal combustion engines were virtually nonexistent 40 years ago when the first volume of the *Journal of Catalysis* was published [1]. Today, exhaust catalysts are found on nearly all US passenger cars, light- and medium-duty trucks, and even some heavy-duty trucks. The history of catalytic exhaust gas after-treatment — the largest application of heterogeneous catalysis by many measures — is a complex one, involving numerous players (automobile manufacturers, government agencies, catalyst suppliers, petroleum refiners, and fuel-additive suppliers, among others). Their contributions go far beyond advances in catalyst technology alone, and several detailed reviews have been published that cover the broad waterfront of automotive emissions control [2–9]. The catalytic advancement is through constant analysis of the exhaust gas using gas analyzers and the spectrometers. There are several different technologies used for gas analysis, but most exhaust gas analyzers built for shop use are infrared detectors. They work by measuring the infrared (IR) energy absorption of the exhaust gas. Energy radiates in different frequencies or wavelengths. The longest waves are radio frequencies; microwaves are the next shorter frequency, then infrared, followed by visible light. Though its wavelength is too long for our eyes to detect, IR energy is often referred to as infrared light because it behaves the same way; it is reflected by a mirror and is blocked - or more accurately, absorbed by non-reflecting surfaces. A simple example for the gas analyzer is the spectrometer.

A spectrometer is an optical instrument for measuring properties of light. The measured variable is often the light intensity but could also be the polarization state, for instance. The independent variable is often the wavelength of the light, usually expressed as some fraction of a meter. Spectrometer is a term that is applied to instruments that operate over a very wide range of wavelengths, from gamma rays and X-rays into the far infrared.

Based on the spectrometer operating principle, the students were made to build a simple opacity meter in order to understand the working principle of the gas analyzer. Also, the students analyzed exhaust gas using a shop gas analyzer. They tested different cars in order to understand the advances in emissions control technology. After these experiments, a discussion session was held regarding the technological improvements in the exhaust systems and also regarding the alternative – pollution free – energy sources for the automobiles. The goal was to motivate the students to pursue science and engineering careers and enter a field in which they could personally contribute directly to the betterment of day-to-day life for many people.

Program Outline

- We gave a general talk about planet earth and the importance of a clean environment – air, water etc for human wellbeing
- This was followed by an open-forum discussion with the students about the different types of pollution that affect solids, liquids and gases
- The discussion was then narrowed down to air pollution and the different sources of atmospheric pollution
- The students were next taken to the automotive technologies shop where they were trained in the safe and correct use of the shop gas analyzer and their home-made opacity meter
- The students took different readings to understand the composition of exhaust gases
- Finally, the students returned to the class room to discuss about their experiment
- The activity concluded with a discussion about the alternate energy sources that can produce pollution-free energy like battery-operated cars and fuel cell-operated cars.

Procedure

The initial stage of the program was conducted in a regular class that normally runs for 45 minutes. The science teacher gave a brief outline about the purpose and the importance of the program. Students were then asked a series of questions regarding the solar system, the planets in the solar system and what makes the planet earth special, the idea being to get them involved into the discussion and to raise questions about the different aspects of our planet. The focus was then turned towards the essential features of our planet which make life possible in our planet i.e., water and air. The importance of clean air and clean water for a healthy life were brought out through a series of examples. The recent flooding disaster in New Orleans was used as an example to demonstrate that how bad living conditions could get if the water gets contaminated. Also, some other examples like industrial pollution to water sources were discussed. The students were really getting into the program by asking highly pertinent questions about the causes of pollution and also sharing their suggestions about what could be done to avoid or limit the extent of the pollution. Followed by these brief discussions, the attention turned towards air pollution; the major concern of the planet. The students could respond immediately that the two major sources of air pollution are automobile exhaust and from chemical industries. A detailed discussion was held regarding the effects of automobile pollution on the atmosphere and the engineering advancements that help control pollution level.

For a better understanding of the problem, the students moved on to the next stage, i.e., to the automobile shop. Here, the teacher explained about the different part of the automobile system. The teacher explained about the working of the exhaust system and also about the engineering advances in exhaust systems technologies in the past 50 years. The students did some experiments by checking the exhaust emission at different conditions in two different vehicles. The experimental readings were taken when the engine is at idle, at 1000 rpm and at 2500 rpm. The readings were taken using a probe that was connected to a computerized gas analyzer. The gas analyzer gives the output data for the different conditions. The output data contains the information about the amount of different gases present in the exhaust gas, like, CO, CO_2 and the other hydrocarbons. The output chart gave an idea about the amount of emissions present for the different rpm and for different engines. That enabled the students to think about the ideal conditions for minimal pollution levels. Also, the discussions made the students aware about the fact that the engine and the carburetor should be tuned regularly for most complete combustion of the fuel, which is one other way to control pollution levels. The students were also involved in a simple project to understand the working principle of the spectrometer, wherein they built a simple opacity meter based on the spectrometer principle to measure the variation in the light intensity for different emission conditions (See Appendix for details).

Collecting Data

During the opacity meter testing, the sensor diode was monitored by a multimeter set to millivolts. Because the meter is very sensitive to changes in voltage within the diode, each sample was tested three times to represent the full scope of the readings. Then the three different numbers were averaged for each sample for comparison. The following graphs and tables document the results of the experiment.

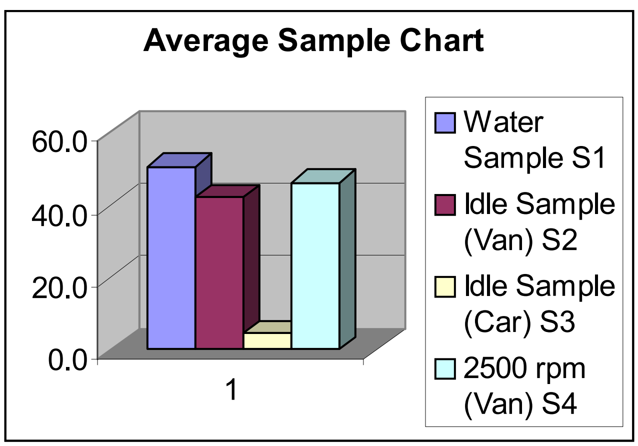

Figure 1. Opacity meter readings (mV) for various exhaust condensate samples

	Water Sample S1	Idle Sample (Van) S2	Idle Sample (Car) S3	2500 rpm (Van) S4
T1	50.0 mV	40.0 mV	4.6 mV	47.0 mV
T2	53.0 mV	45.0 mV	5.0 mV	46.3 mV
T3	49.0 mV	42.0 mV	3.6 mV	45.8 mV
Average	50.7 mV	42.3 mV	4.4 mV	46.4 mV

Table 1. Sample readings from opacity meter

Discussion

The results helped the students conclude that engine efficiency has much to do with the amount of pollutants in the exhaust gases and liquids. The sample taken from the vehicle with a defective injector was a dark brown color. Using the opacity meter, the value of only 4.4 mV showed that the sample was far from being near the consistency of pure water. Many impurities and combustion residues must have been contained within the sample to so drastically change its color and chemical makeup. However, the sample from the fine-tuned vehicle was much more compatible with that of the water sample. To the naked eye, the two clear samples looked indistinguishable. Even at idle, the van sample differed only 8.4 mV from the water sample, showing that its consistency was much more like water than the sample from the inefficient engine.

In comparing the samples taken when the Mazda Van was running at idle and at 2500 rpm, it was discovered the sample taking at higher rpm was slightly cleaner. Engines tend to burn more efficiently at higher rpm, reducing the amount of contaminants in exhaust water. In this case the higher rpm caused the number to jump from 42.3 mV at idle to 46.4 mV at 2500 rpm. With the tap water readings from the opacity meter at 50.7 mV, the exhaust sample at 2500 rpm closely approaches the chemical makeup of the tap water sample. Such a conclusion is consistent with the gas analyzer results in which hydrocarbons and carbon dioxide were higher at idle.

After the experimental stage, the students returned to the class room for the final session of the program. The discussion started with what they learned in their experiment about the exhaust systems and the impact of exhaust emissions on the atmosphere. By now, the students had a real time experience about the effect of the exhaust emissions on the human body. The whole time during the experimental observation and the sample collection, the students were exposed to the exhaust emissions. That made the students realize about the amount of emissions from automobiles everyday into the atmosphere. The students came up with different ideas like developing improved exhaust emission systems for automobiles, limiting their driving times, car pooling etc. Also, the students talk about the other forms of energy that can be used for cars like battery-operated ones. But they were not familiar about the concept. The discussion then turned towards the different types of alternative energy sources like the batteries and fuel cells. The emphasis has been given to fuel cells by describing the principle of fuel cell, different types of fuel cells and their emissions-free operation. A detailed talk had been given to the students regarding the advantages of the fuel cell and the current research activities that have been going on in the fuel cell development. Towards the end of the talk, the students got into a lively discussion regarding the development of fuel cell research, their opportunity to get into the automotive field related fuel cell research, the demand for the fuel cell scientist in the market and eventually the pay scale for the mechanical, materials and chemical engineering graduates.

Concluding Remarks

The program has been designed and executed as expected. The overall aim, to generate awareness among the students about the environmental issues and to generate interest in applying engineering concepts to practical problems, has been carried out convincingly. It was evident that the students were interested in a career where they could use their strengths and talents and interests in automotive technologies. This program helped the students to understand that engineering is one career where they can be what they want to be. However, due to time limitations, the authors could not conduct questionnaire sessions among the students. The authors plan to do a questionnaire survey among the students and also to arrange a field trip to the university's research lab involving fuel cell research in the following summer.

Acknowledgement

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Appendix

Based on the spectrometer operating principle, a simple opacity meter (Appendix Fig. 1) was built using the Styrofoam block in order to demonstrate the working principle of the gas analyzer that is used to analyze the exhaust gas from the automobile. Normally during combustion, in addition to exhaust gases, gasoline engines also expel liquid emissions. However, the question arises, are contaminamts created by the stresses of combustion present in these water emissions? How similar is this exhaust water to tap water? Does its consistency change at different rpm and with differences in engine efficiency? This experiment sought to answer these questions by testing liquid exhaust emissions at 500 and 2500 rpm against a sample of tap water. The opacity meter was used to test the purity of each sample. However, such a rudimentary spectrometer only detects the presence of impurities but doesn't reveal the identity of the foreign matter. A gas analyzer was used to see what the emissions consisted of and to confirm that the opacity meter's readings were accurate. This experiment will help students appreciated how emissions change with engine efficiency and rpms.

Procedure

The first portion of the experiment involved the creation of a simple opacity meter. A half-inch hole was drilled through a styrofoam block from one side through to the other. Then another half-inch hole was drilled from the top of the block until the two holes met in the center. The two cavities form a T shape within the block. The top hole was to insert the samples for analysis. One of the side holes was for the light from the LED flashlight to enter and the other contained an LED to collect the amount of light passing through the shaft. It was ensured that the LED would collect light only from the flashlight and all the other openings were sealed tightly to eliminate other light sources.

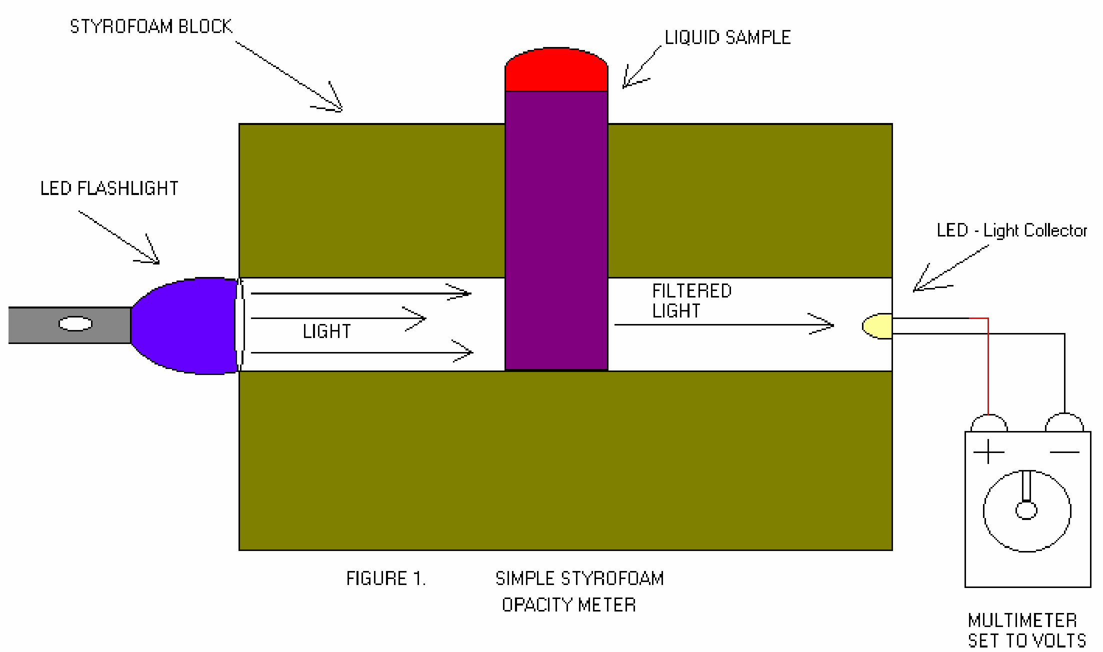

FIGURE 1. SIMPLE STYROFOAM OPACITY METER

After the opacity meter was built, liquid emissions were collected from the exhaust of two vehicles, a 1991 Mazda MPV Van and a 1989 Nissan Maxima. Both vehicles had water samples collected while they were at idle and the Mazda Van had a sample collected at 2500 rpm. The Nissan Maxima had an injector that was leaking, causing the fuel to burn less efficiently than the properly tuned Mazda Van engine. All samples were compared against a sample tap water using the opacity meter built for the experiment.