Case Study 3 – Low Cost Particulate Removal Device

1. Context

The transportation sector in Hong Kong plays a significant role in moving cargo and goods within Hong Kong and to the rest of Mainland China. Roughly 220 million tonnes of goods pass through Hong Kong's container ports every year and, in 2004, there were 110,000 goods lorries registered by the Transport Department. Hong Kong depends heavily on these services in order to maintain its status as a major regional logistics hub for the PRD and Southern China.

Figure 1. Lining up to go

2. Air Pollution Problem

Hong Kong is facing serious air pollution problems, in particular, from high street level particulate concentrations. These particulates come mainly from diesel vehicles, such as goods lorries as well as buses and coaches. Diesel particulates are reported to have carcinogenic properties as the fine particulates can penetrate and remain in respiratory systems.

The Government identified the problem in the 1980s and has taken numerous corrective actions since then. These include:

- Adopting tighter fuel and vehicle emission standards;
- Adopting cleaner alternatives to diesel where practicable;
- Encouraging diesel vehicle owners to control emissions with devices that trap pollutants;
- Strengthening vehicle emission inspections and enforcement against smoky vehicles; and
- Promoting better vehicle maintenance and eco-driving habits

Despite all these actions, street level particulate concentrations are still of concern and there is a need to further reduce particulate emissions from diesel vehicles such as the one shown in Figure 2.

Figure 2. Diesel Truck

3. Solution

A particulate removal device for diesel engines for installation in heavy diesel vehicles has been designed, developed and tested by the Hong Kong Polytechnic University[1]. The technology is based on separation of particulates from the exhaust gas by centrifugal force and subsequent filtration of the particulates for storage as shown in Figure 3. The working principle can be briefly described as follows.

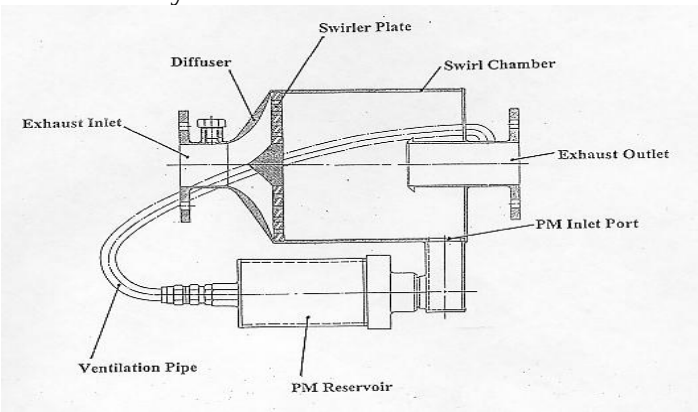

Figure 3. Particulate Removal Device Schematic

- Exhaust gas is guided to a swirler in order to generate the swirling motion in the exhaust gas;
- The swirling motion helps to separate the particulates from the exhaust gas;
- The separated particulates will subsequently be guided to a particulate reservoir where the gas stream carrying the particulates passes through a filter for storage therein; and
- The filtered gas stream is then redirected back to the exhaust pipe of the vehicle.

The technology has the capability of reducing particulate emissions from diesel engines of all capacities even with fuel of a high sulphur content. The device can be retrofitted at any location of the exhaust system including the tail pipe exit.

4. Implementation

The particulate removal device (see Figure 4) was designed to give a negligible back pressure increase. Before installing the device, it is necessary to make sure that the engine is adequately tuned and the back pressure and the smoke level of the vehicle should be measured to obtain a baseline. These two parameters are measured again after the installation of the particulate removal device.

In all vehicles tested by the University, the back pressure increase was found to be minimal and did not affect the engine performance.

[1] The Particulate Removal Device (PRD) was developed with funding support from the Innovation and Technology Commission (ITC) under Project No. ITS/080/03.

Figure 4. The installed particulate removal device

As there are no moving parts in the device, maintenance is minimal. The only part that needs attention is the filter in the particulate reservoir as this has to be changed at regular intervals, which vary from vehicle to vehicle depending on the age and make of the engine, and the type of diesel fuel used. There is no need to clean the particulate removal device and staff can be trained on how to change the filter, which is designed for easy installation much like an oil filter in the engine.

The particulate removal device is made of stainless steel. Once installed, it lasts for a long time. Therefore, inspection need only be limited to the mounting. Monitoring is carried out by measuring the smoke emitted from the exhaust. Changing is only necessary when there is substantial deterioration.

5. Outcomes

The University has already conducted initial design, development and testing of the particulate removal technology in collaboration with CityBus Ltd and many other companies such as Vitasoy, Argos Bus Service Co. Ltd, HK Dumper Truck Drivers Association, and Organisation of HK Drivers.

Several preliminary designs of the particulate removal device have been tested in the laboratory to demonstrate its capability in reducing smoke opacity and particulate concentration. The tests demonstrated a reduction of smoke opacity from 31% to 65%, and a particulate concentration reduction from 18% to 57%. These initial tests also showed that the technology was capable of reducing the concentrations of both micron-size and submicron-size particulates.

The performance of the device was further tested in an independent test centre, the Emission Test Centre of Hong Kong Limited. The results showed a maximum reduction of particulate mass by 31.4% tested to 98/69/EC type 1 test procedures.

Field tests have also been conducted on buses and trucks of 4 tonnes or higher capacity. Based on road test results, it was found that the filter in the particulate reservoir needed replacement after an average distance of 10,000 km. A new filter was installed after the

used filter was removed for additional testing to determine the amount (by mass) of particulates collected during the period covering 10,000 km. Smoke tests were also carried out on the diesel vehicles installed with particulate removal devices. In general, it was found that smoke opacity was reduced by 25% to 68%.

6. Cost Benefits

The manufacturing cost of the particulate removal device is estimated to be HK$8,000 and the installation cost comes to around HK$2,000. Each filter is estimated to cost about HK$60. After numerous tests, it was found that there were no fuel savings after installation of the device. However, the particulate removal device does not contribute to any deterioration of the performance of the engine and does not result in any increase in fuel consumption.

7. Transferability

Transferability opportunities exist for this technology, for instance with stationary diesel engines and marine diesel engines. The University has been contacted by Mitsubishi Heavy Industries (HK) Ltd and Fleetguard Inc. with an interest to acquire the rights to manufacture the particulate removal device for use in East Asia (see Figure 5 below)..

Figure 5. Potential applications for the particulate removal device

8. Conclusions

The particulate removal technology can reduce particulate emission by 30%, is inexpensive and can be used for mobile and stationary diesel engines. The limitation of the particulate removal device is in the particulate reservoir and the filter. Further work is required if this limitation were to be removed.

Contact:

(Hong Kong Polytechnic University)

Prof. SO, Ronald Ming Cho, 2766 6642, mmmcso@polyu.edu.hk
Dr. CHEUNG Chun-shun, 2766 7819, mmcsc@polyu.edu.hk
Ir. LO Kok-keung, 2766 7816, mmkklo@polyu.edu.hk