Lack of applicable criteria in non-exhaust emission legislations: AWPER index a practical solution

Most research on particle emissions have focused on exhaust-emissions. In this regard, many different legislations have been directed. Euro VI emission, Tier 4 and 97/68/EC NRMM directive are some of the latest legislations which introduced some limitations on the levels of NOx, HC, CO and PM in engine exhaust. These standards introduce applicable criteria to limit the exhaust emissions from both road and rail transport.

However, no criterion has been defined to measure the amount of non-exhaust emission which are mainly produced by wear processes. In a recent study, we introduced airborne wear particles emission rate (AWPER) and applied this index to compare airborne particles generated by different braking materials.

1. Introduction
Humans are subjected to risks from particles through different routes. The routes of exposure can be classified as:
- Contact with the skin (dermal)
- Breathing (inhalation)
- Drinking or eating (ingestion or oral)
- Injection

Fig. 1 shows a view of how particles enter the blood through different routes. In fact, the particles toxic effect starts when the accumulated amounts of elements exceed the certain amount which can be tolerated by the natural metabolism. In the human body

Among these different routes, inhaling has a more intense and rapid the respiratory system. Figs 2-4 show different parts of upper respiratory and lower respiratory tract. As it has depicted in Fig. 4, the nano-sized particles (Dp < 650 nm) can reach to the deepest parts of lung and can directly enter to the blood.

The adverse health effects of particles on human health motivated national and international organization to limit the amount of particles emission. Euro VI, Tier 4 and 97/68/EC NRMM are the recent approved legislations which oblige engine manufacturers to concern the new criteria. However, these legislations concern only exhaust emission and mainly carbon based particles. Recent studies show that the metal based particles, particularly those containing copper, are more toxic than exhaust emission of engines. These results necessitate more studies in non-exhaust emission and introducing new criteria to limit the amount of those particles.

Wear processes in both rail and road transport are the main sources of non-exhaust emissions. Note that some wear particles can become airborne during the wear process. We refer to this property as the airborne wear particle emission rate (AWPER).

AWPER is defined as the ratio of the mass of generated airborne particles (in mg) to the length of time (in h) two objects are sliding against each other under controlled conditions. The sliding velocity (in m s\(^{-1}\)) and the mean contact pressure (in MPa) between the two objects remain constant in these conditions.

In the presented study, we used AWPER indices to compare the amount of wear particles generated by four different braking materials. In this regard, a special set-up was used on a conventional pin-on-disc machine.

2. Method

We used a modified pin-on-disc machine (Fig. 2) and studied the characteristics of particles generated by different braking materials. The mass concentration of particles were measured when the pins were sliding on discs.

This set-up resembles the box model (Fig. 6) and the mass concentration in the sealed chamber of pin on disc machine can be derived as follows (equations 1-3):

\[ C(t) = \frac{q}{q-n} + \frac{C(0)}{q-n} \]

\[ \text{AWPER} = \frac{q\cdot C(0)}{q-n} \]

\[ \text{AWPER} = C(0) \cdot \text{inlet airflow} \]

3. Results

Fig. 7 show some typical results of AWPER for four different railway braking materials. The mean contact pressure was 0.87 MPa and the sliding velocity was 12.4 m/s in all tests. The mean value was calculated for the first 600 s of each test.

4. Conclusion

The following conclusions can be drawn from this study:
- The AWPER value of the organic brake pad against steel brake disc was considerably higher than sintered brake pad against steel brake disc.
- The AWPER value of the organic brake block against railway wheel was considerably higher than cast iron brake block against railway wheel.
- The AWPER index is suggested to be used as a comparative index either in legislation or for ranking different braking materials in rail transport or even road transport.