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Automobile braking system: Cause of Air Pollution

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ABSTRACT

The pollution from automotive sector is the global issue of concern. Globally, automotive industries are following exhaust emission norms to reduce various gases and particulate matter in case of diesel engines. In urban area, now air pollution due to braking is observed as a major contributor. Brake wear particulate matter (PM) of the automotive system is emitted in to air as fine particles. Considering the strict controls on vehicle exhaust emissions especially of PM, the relative contribution of brake wear particles will become increasingly important in the consideration of total PM emissions.

The metals particles released from brake wear have a great effect on human health. When metal particles enter through nose of human being, they damage lungs as well as lowers breathing capacity with increase in pro-inflammatory responses leading to stress while breathing. In braking system the contact between the disc and the friction pad generates particles of various sizes. When brakes are applied braking system generates friction between disc and the friction pads, which converts vehicle kinetic energy into heat energy. Vehicle brakes are subject to large frictional heat generation with subsequent wear of linings and rotors apart from the mechanical abrasion. This friction produces micron-sized wear particles of both disc and friction pads. Even the electric vehicles do contribute the same braking pollution as of fuel combustion vehicles. This assessment observes the major brake wear particles during the braking system and its contribution to the environment pollution over a cycle of two pad wear on disc brake.

Keywords : *Brake, friction, pads, air pollution.*

1. Introduction

Pollution is worlds burning issue, every country is facing pollution in one and another form. When it comes to air pollution, every one points towards the vehicles exhaust pollution. One have made strict norms for the vehicle exhaust emission; still it is on rising way. Whenever one discuses about exhaust pollution one forgot to consider the non exhaust pollution made by automobiles. It has been found that brakes in automobiles are also the major cause of pollution.

Running vehicle is stopped by applying brake; almost all vehicles have brakes in different forms. This stopping action is carried out by applying friction between wheel disc / drum and friction pads specially designed to create greater friction. The friction pads are made up of fine metal particles, bonded by chemical binder. When the friction pad and disc / drum of wheel come in to contact, fine particles of bonded friction pad gives away due to friction. This particle gets mixed with air as a particulate matter (PM). Exhaust emission norms

are becoming strict therefore PM pollution is decreasing but non-exhaustive PM are increasing. Studies shows that in urban environments, brake wears contribute up to 55 % by mass to total non-exhaust traffic-related PM10 emissions and up to 21 % by mass to total traffic-related PM10 emissions, while on highways, this contribution is lower because of lower braking frequency [1]. Brake dust mainly contribute to the PM10 where as PM 2.5 is on lower side. Subtypes of atmospheric particles include suspended particulate matter (SPM), thoracic and respirable particles, inhalable coarse particles, which are coarse particles with a diameter between 2.5 and 10 μm (PM10), fine particles with a diameter of 2.5 μm or less (PM2.5), ultrafine particles and scoot [2]. Friction pad material can be classified as metallic, mineral, ceramic or organic. They mainly consist of copper, steel, brass, potassium titanate, glass, organic material and Kevlar. Fillers are used in order to improve thermal and noise pad properties and also reduce the manufacturing cost. They usually consist of inorganic compounds (barium and antimony sulphate, magnesium and chromium oxides), silicates and ground slag, stone and metal powders [3]. Braking is always accompanied by wear of both brake discs and brake pads and along with the intensity of the braking; the formulation of the brake pads significantly influences the wear rate of brake pads as well as brake discs [4].

2. Braking System

The function of the braking system is to reduce the speed of the moving vehicle or bring it to rest in a shortest possible distance whenever required. Brakes are mechanical devices by increasing the frictional resistance they retards the motion of the vehicle wheels. It absorbs either KE or PE or both while in action and this absorbed energy released in the form of heat. While moving down a steep gradient or in an emergency situation the vehicle is controlled by the application of brakes. If brakes remain in action for a longer period they dissipate the braking heat to atmosphere as rapidly as possible.

Automobiles are fitted with two brakes; the service or foot brake and the emergency or hand brake. The foot brake is used to control the speed of the vehicle and to stop it, when and where desired, by the application of force on the brake pedal. The hand brake, applied by a lever, is used to keep the vehicle from moving when parked. Virtually all vehicles are now equipment with four-wheel brakes. In most of the vehicles disc brakes are fitted on the front wheel where as drum brakes are fitted on rear wheels, this is because disc brakes are more effective than drum and by this combination vehicle can be bring rest at a faster rate. The front brakes must operate without interfering with the steering action. The brakes must be capable of decelerating a vehicle at a faster rate than the engine is able to accelerate it. Normally brakes have to absorb three times the amount of engine horsepower energy in its equivalent form. Friction pads are used in both the brakes only they differ in shape as shown in Figs.(1,2).

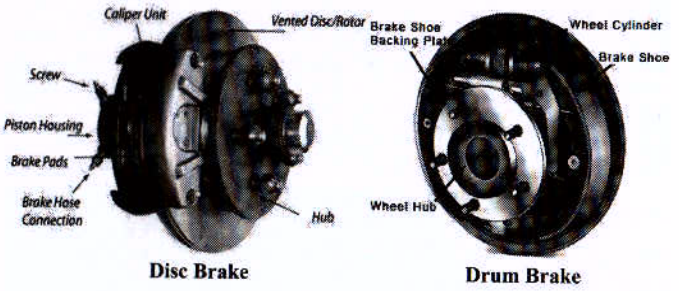

Fig. 1. Disc Brake and Drum Brake assembly used in automobiles

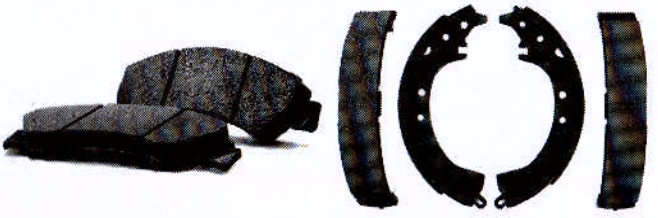

Fig. 2. Friction pads of Disc and Drum Brake

3. Brake Emissions

Friction pads are manufactured from the fine particles of different metals. The brake pads are manufactured from different finolic resins based friction composites manufactured by cold or hot mold pressing followed by several other post curing processes [5]. The main constituents of pads are copper, steel, brass, potassium titanate, glass, organic

material and Kevlar. Inorganic compounds are used as binders such as barium, antimony sulphate, magnesium, chromium oxides, silicates and ground slag, stone and metal powders. The particles released from braking system depends on various factors i) brake friction material i.e. contents of Non-Asbestos Organics (NAO), carbon composites, low-alloy steel, semi-metallic components, rotor and drum parts. ii) Brake assembly type- assembly size, surface structure, grooves iii) Brake operating conditions like vehicle speed, deceleration rate, pressure, torque and temperature generated [6]. It has been observed that for normal operating temperatures, the pad wear per unit energy absorbed is independent of speed. It is only influenced by brake pressure and other behavior. A driver who applies the brakes more aggressively will have more wear than a driver who always smoothly increases the brake pressure to its steady state level. The influence of brake pressure in pad wear is easy to model even though it would require a significant amount of testing and verification [7].

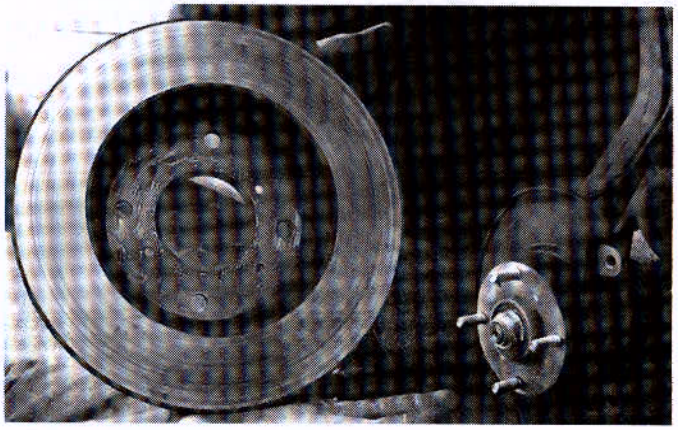

Fig. 3. Dust Formation in Disc Brake

Copper Iron Powder Steel Chips Brass

Fig. 4. Brake wear debris

Friction between Disc and friction Pads leads to dust formation as shown in Fig.3. Particles in the form of dust are the wear of friction pad material as shown in Fig.4. It may contain known or even if unknown particles; which the different companies are using it as there secrete formulas. The general metal content in a brake pad are given in Table 1.

Table 1. Metal Content of Brake Pads

Metal	Concentration Range (mg/Kg)	Metal	Concentration Range (mg/Kg)
Fe	115000-400000	Mn	3,220
Cu	15,100-142,000	Zn	270-21,779
Cr	162-1200	V	660
Co	6.43	Sr	81.4-740
Cd	2.7- 29.8	Ti	3,600
Ca	14,300	Sn	6,998
Ba	2,640	Se	20
Al	3,769	Sb	10,000
As	10	Pb	1,959-3,900
K	857	Ni	210-849
Mg	6,140	Na	15,400
Li	55.7	Mo	10,000
Mn	3,220		

4. Discussion

Brake wear contains particles from all fractions involved in the respiratory function. Some constituents of airborne brake wear particles have been identified as dangerous for the human health. Air pollution affects on human body from both side; by respiration from internal side and skin, ears, hair and eyes from external side.

There are many factors contributing the air pollution. Figure 5 shows the eye irritation problems due to city pollution at Aurangabad in Maharashtra (India). The air pollution level is higher due to industrial area around the city as well as many more old structures are being demolished and new buildings are being constructed for residential purposes. These demolition causes large dust formation. Secondly cleanliness of the city is a major issue which generates lot of dust. Number of vehicles increased means traffic jam problems, as Aurangabad is a old city roads are narrow, therefore application of brakes will increases leading in to braking pollution. According to WHO recently released report [8], out of 15 most polluted cities 14 cities are from India. This is the most alarming situation for Indian environmentalist. Report again states that there are 13 cities from India in which Particulate

Matter level is at the most dangerous level i.e.10 Micrometer (PM10). Out of total deaths from pollution one fourth deaths takes place in India, Delhi and Kanpur are s the most polluted city in India. According to World Banks Cost of Pollution report [9], pollution not only affects on health but also on GDP of that country. In the year 2013 India loses its 505.1Milian Dollar which counts total loss of 7.69% of GDP.

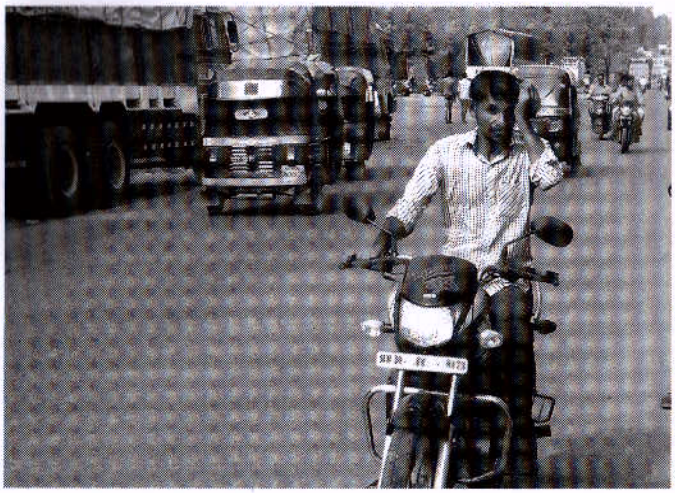

Fig.5. Photograph showing eye irritation problems due to city pollution

Several studies show that the nano size particle of size PM2.5 effects on the different parts of the body, the organs like liver, nervous system, brain and pulmonary interstitial which absorbs directly by the respiratory system and transfers it to the blood cells. Brake pads are manufactured with different compositions, depending upon the contents of materials and manufacturing procedures brake pads are prone to wear. Copper and antimony are considered as the most harmful elements. Industries are trying to produce low dust particle brakes. Consistently copper percentage has been reduced from the modern brakes form 15% to 5% [10]. Modern production of disc brake should be less pollutant with thermally treated disc having lower complicated and costly material along with machinability characteristics[11]. During braking dust particles of disc as well as pads emitted, for soft braking, particle size is low as compared to hard braking, but at the same time there are chances of struking the large size particles in between friction pads and disc and further reducing the size due to more rubbing [12]. This happens in long and hard braking situation; again here one additional parameter enters in this process that is heat generated during the constant and hard braking for a prolonged period. This generated heat affects on the dust formation, at low temperature dust formation and particle size is small as long as the temperature increases the particle size increases and simultaneously bonding also affected by this generated heat [13]. For developing better disc brakes tribological behavior plays a very important role. The selection of correct material and non-dust formation coating over the disc and pads may be the solution in future [14]. In industries FEA method is widely used to analyze the thermal and other behavioral effects of two contacting materials [15, 16]. FEA analysis also shows that there is effect of heat generation on the braking performance, as more heat is generated the thermal expansion is observed in the disc and pads. Due to thermal deformation contact area between disc and pads also changes, thermal and mechanical deformation affects in between rubbing surfaces. Simultaneously the braking pressures also a great impact on the overall friction mechanism. This changing phenomenon will lead to generation of different PM particles. The wear of the disc and pads is also important since it changes the gap between the two. The wear particles flow will largely depends upon this gap [17- 19]. The European Union funded project is trying to reduce this brake emission by 50% [20]. In this project different attempts are being tested for reducing the emission, one of them is to developing best braking practices amongst the driver by providing the smart dashboard, driver may adjust his individual braking style to reduce the emission. Lowbrasys system will help to reduce the emission due to braking; this system may hit automobile market at the end of 2018 [21].

5. Conclusion

Large part of the urban population is facing the issue of non-exhaustive pollution. Automobile pollution controlling authorities are mainly concentrating on exhaustive emissions and ignoring the non exhaustive emission like brakes. Increased numbers of automobiles are also contributing in the

non exhaustive emission, causing serious problems of health. The material compositions used by different brake pad manufacturers are very harmful to human health. This may be the urgent issues to be concentrate for the sake of environment and human health.

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