ABSTRACT

In recent years, the automobile industry has been facing substantial technical challenges as it seeks to improve fuel economy, reduce vehicle emissions, increase styling options and enhance performance. The application of Metal Matrix Composites (MMCs) as new brake drum materials to brake components has been receiving worldwide attention, because of their light weight, superior mechanical properties, high thermal conductivity, specific heat and better wear resistance than cast iron. Since the brake drum represents part of the unsprung rotating masses, the reduction in their mass will help in increasing the vehicle dynamics and ride comfort.

MMCs have emerged as a class of advanced materials capable of advanced structural, aerospace and automotive applications. MMCs have matured for the last two decades and are under research for structural component applications such as pistons of internal combustion engines, connecting rods and brake calipers subjected to cyclic loads. Among different MMCs, particle reinforced Aluminium Metal Matrix Composites (Al MMCs) are attractive because of their isotropic properties and ease of manufacturing in large volume. Although different reinforcements for aluminium are reported in the literature, the Silicon Carbide (SiC) particle reinforcement is found to have good interface and finds widespread applications.

The brake drum of a typical passenger car has been selected for the study. The Al MMC has been selected based on the properties required for the
brake drum. The aluminium alloy A356 has been selected as matrix for manufacturing the MMC based on the ease of manufacturing. The silicon carbide particles of size 43 microns have been used as reinforcement for manufacturing the Al MMC. The brake power absorbed by the brake drum during single stop, continuous and repeated braking conditions has been computed. The inner radius and inner width of the Al MMC brake drum were optimized with the objective of minimum temperature rise using Genetic Algorithm. A net reduction in temperature rise of 187.2°C is achieved for the Al MMC brake drum by optimizing the parameters. Also, a weight reduction of 20% is achieved for the Al MMC brake drum.

The Al MMC brake drum has been manufactured through the dispersion technique using an electric resistance type furnace with a temperature controller. The MMC brake drum has been fabricated by adding 25% silicon carbide as reinforcement.

A brake drum test rig has been fabricated for the experimental analysis. It has the provision to mount the brake drum and to rotate it at different speeds. A carrier plate which contains the shoe assembly has been mounted on the drum shaft using a bearing and it is kept stationary using a load measuring device. A master cylinder with a pressure gauge has been mounted on the test rig to apply different braking forces. The brake torque absorbed at the friction surface has been measured using a spring balance and the applied brake force has been measured from the pressure gauge. Thermocouples have been inserted in the brake drum to measure the temperature rise and connected to the temperature indicator through slip ring arrangement.
Tests were conducted to determine the dynamic friction coefficient, brake torque and temperature rise. A constant brake line pressure of 10 bar was applied for 2 minutes and the brake torque has been measured. The test was repeated for three times and the average value of the brake torque and the dynamic friction coefficient were determined. The brake torque absorbed in the cast iron and the Al MMC brake drum for various brake line pressures has been observed using spring balance. It is observed that the brake power absorbed by the MMC brake drum is more than the cast iron brake drum for the same applied brake line pressure. The dynamic friction coefficient of cast iron and the Al MMC brake drum are found to be 0.425 and 0.475 respectively. When tested at a brake line pressure of 10 bar for a braking time of sixty seconds, the temperature rise in Al MMC brake drum is 10 °C higher than the cast iron brake drum. This is due to higher brake power absorbed in Al MMC brake drum because of 0.05 increase in dynamic friction coefficient.

The static analysis has been performed using theoretical and finite element techniques. The stress and the deformation of the cast iron and the Al MMC brake drum have been computed and compared. In both the analyses, the stress and deformation of MMC brake drum has been found to be lower than the cast iron brake drum. The thermal analysis has been performed using theoretical and finite element techniques to determine the temperature rise during braking. In single stop braking, the temperature rise in Al MMC brake drum is observed to be less than the cast iron brake drum. During repeated braking, the temperature rise in Al MMC brake drum is observed as 3 to 7 % more than the cast iron brake drum. During continuous braking, the
temperature rise in brake drum is observed as 2 to 6% more than the cast iron brake drum.

The wear behaviour of Al MMC sliding against asbestos based brake shoe friction material has been compared with the conventional grey cast iron. The wear tests have been carried out on a pin on disc machine with pin as brake shoe friction material and discs as A356/25SiCp Al MMC and grey cast iron materials. Pins of 10mm diameter have been machined from a brake shoe lining of a passenger car. The grey cast iron disc has been machined from a brake drum of a passenger car. The Al MMC disc has been manufactured by dispersion technique and machined to the required size. The friction and the wear behaviour of Al MMC, the grey cast iron and the brake shoe friction material have been investigated at different sliding velocities, loads and sliding distances. Mathematical models have been developed to predict the wear rate using a linear factorial design approach. The parameters $x_1$, $x_2$ and $x_3$ have been used to represent the load, sliding velocity and sliding distance respectively. Good agreement has been observed between predicted and experimental results. The present investigation shows that the Al MMC has considerably higher wear resistance than conventional grey cast iron, while sliding against brake shoe friction material under identical conditions.

The suitability of Al MMC brake drum for automotive application is evaluated based on the weight, wear, friction coefficient, temperature rise, strength and cost. From the present study, it is concluded that the A356/SiCp Al MMC is a better suitable material for brake drum application of passenger car.