ABSTRACT

Enhancement of an automobile engine efficiency have been investigated since from the initial development of an engine. The enhancement can be achieved by optimizing the geometric design parameters, selection of durable alloys and improving surface properties of the engine elements such as piston, piston pin, piston ring, connecting rod, crank shaft, valves and cylinder liner. These components are involved in the generation of engine output, therefore the performance of the engine depends on the durability of these engine components.

A detailed literature survey was carried out in the areas of engine performance, emissions, piston geometry, piston surface conditions and alternative fuels. This literature survey was clearly depicted that, need of piston alloy developments with enhanced mechanical and thermal properties for achieving the better engine performance. Therefore this research work was carried out to develop the intermetallic based pistons with enhanced properties and to investigate the engine efficiency and emissions due to implementation of developed intermetallic based pistons. This intermetallic based pistons were made up of Al-Si alloys with intermetallic precipitates such as Al_{12} $(Fe,Mn)_3Si_2$, Al_5FeSi , Al_9FeNi, Al_3Fe, and $AlMg_2Si$, these compounds can be formed when the addition of alloying elements such as Fe, Cu, Mg, Mn, Ni and Si more than the solubility limit with liquid aluminium.

Initially piston alloys were developed in low, medium and high volume fractions of IMC namely type A, type B and type C alloy. Mechanical, thermal and metallurgical characterization of these alloys were

done as per American Society for Testing and Materials standards. Mechanical properties such as hardness, proof strength and tensile strength have shown increment in type B and type C alloy when compared to type A alloy. Type B have shown 8.6% increment in hardness, 5.6 % increment in proof strength and 7.35% increment in tensile strength when compared to type A alloy. Type B have shown 14% increment in hardness, 7.35 % increment in proof strength and 6.85% increment in tensile strength when compared to type A alloy.

Thermal characterization of intermetallic based piston alloys have shown better specific heat capacity in type C and type B alloy than type A alloy. Higher additions of Si, Ni, Cu and Mg led to enhanced specific heat capacity of the piston alloys. Type B and type C alloy have revealed as higher intermetallic compound volume fraction with finer size when compared to type A alloy. Type B and type C alloy were revealed as Chinese script/ star like intermetallic precipitates with denser distribution than type A alloy. Therefore, higher addition of Si, Fe, Cu, Ni and Mg led to precipitate finer and denser intermetallic compounds across the microstructure.

Pistons were made in type A, type B and type C intermetallic based alloy composition by gravity die casting process. These pistons were heat treated with T6 condition and machined to final required dimensions. Type A, type B and type C pistons were fitted into a Hero Honda 100 CC two wheeler and run it for testing the ageing behaviour of pistons by actual field testing. This test was carried out for 0 hr, 1 hr, 2 hrs, 3 hrs, 4 hrs, 5 hrs and 6 hrs of engine operation. Therefore ageing of each piston was investigated from 0 to 6 hrs of engine operation.

Pistons were cut sectioned after the ageing testing in order to reveal the hardness across the piston zones. Ageing behaviour of these based pistons were assessed based on the hardness values across the various piston zones such as crown, top land, ring land, gudgeon pin boss and skirt.

Piston zones of type B and type C pistons have shown higher hardness distribution than type A piston. Type B and type C pistons have proven that better age hardening and better thermal stability than type A piston during an engine exposure up to 6 Hrs. Thermal stability of type B and C pistons have shown better due to denser intermetallic compounds and higher specific heat capacity than type A piston.

Engine characteristic testing was done in single cylinder stationary Kirloskar diesel engine using intermetallic based pistons (type A, type B and type C). Mechanical and thermal efficiency of the engine have enhanced about 11% and 11.56% respectively due to use of high dense intermetallic pistons (type B and type C). Frictional losses have reduced in type B and C piston when compared to type A piston. Therefore, type B and type C piston have shown better engine characteristics due to its better specific heat capacity and higher thermal stability than type A piston.

High dense intermetallic piston (type B and type C) have shown lower NOx, slightly lower CO_2 and slightly higher CO emission due to higher heat absorption by the piston in the combustion chamber. Heat absorption by the piston or heat flow into the piston is higher due to higher specific heat capacity of the piston alloy. Higher additions of Si, Ni, Cu and Mg have led to enhanced specific heat capacity and higher thermal stability. Use of high dense IMC pistons (type B and type C) enhances the engine performance and lowers the NOx emission when compared to low dense intermetallic piston (type A).