Abstract

Aluminium-Silicon cast alloys have become one of the potential engineering material for automotive, aerospace, defense and general engineering applications, where high specific strength and specific modulus, low coefficient of thermal expansion (CTE), good thermal conductivity, good resistance to corrosion and oxidation are needed.

The present work deals with the refinement (refinement of α-Al dendrites in hypoeutectic and primary silicon in hypereutectic), modification (modification of eutectic / proeutectic silicon), mechanical properties (impact toughness, tensile and hardness), dry sliding wear behaviour and machinability (cutting forces and surface roughness) of hypoeutectic, eutectic and hypereutectic Al-Si cast alloys. Properties of Al-Si cast alloys mainly depend on the shape, size and size distribution of second phase particles in the matrix and matrix microstructures. Thus the present work includes the preparation of hypoeutectic, eutectic and hypereutectic Al-Si alloys consisting of fine and uniform distribution of α-Al dendrites, primary silicon and eutectic silicon particles that result in improved mechanical properties, sliding wear behaviour and machinability. The specific objectives of the present work are:

- To standardize a procedure for melting and casting of the different alloys.

- To study the mechanical properties (impact toughness, tensile and hardness), dry sliding wear behaviour and machinability (cutting forces and surface roughness) of the as cast hypoeutectic, eutectic and hypereutectic Al-Si cast alloys.

- Then to investigate the influence of refinement, modification and combined addition of refiner and modifier on the structures and properties of the same alloys. Influence of copper on the mechanical properties (impact toughness, tensile and hardness), dry sliding wear behaviour and machinability (cutting forces and surface roughness) of the same alloys is also evaluated.

This thesis deals with the study of some mechanical properties (impact toughness, tensile and hardness) of hypoeutectic, eutectic and hypereutectic Al-Si cast alloys as well as those of alloys with copper additions. The results showed Al-Si alloys without refinement or modification have low impact toughness, tensile properties and hardness. The impact toughness, tensile properties and hardness increase remarkably after combined refinement and modification along with copper while the alloys only refined or modified showed marginal improvement.

Further the dry sliding wear behaviour of these alloys in uni-directional sliding mode was investigated. Wear tests were conducted at room temperature. According to ASTM-G-99-90, the pins of 8-mm diameter and 25-mm length were fabricated from the castings and run against a hardened and ground (Ra=0.1 μm) En-24 steel disc [Dia-100mm and 8 mm thickness] with a hardness value around Rc 62. The mating surfaces of the pins and the disc were polished to a roughness of Ra= 0.1 μm before the start of the wear test. The wear tests were run under varying normal loads (10.0, 20.0, 30.0, 40.0, 50.0, 70.0 and 100 N), varying sliding speeds (1.0, 2.0, 3.0 and 4.0 m/sec) and varying sliding distances (600, 1200, 1800 and 2400 mts). Dry sliding wear behaviour of hypoeutectic, eutectic and hypereutectic Al-Si alloys mainly depend on the shape, size and size distribution of the α-Al grains in hypoeutectic, primary silicon in hypereutectic and eutectic silicon morphology in the eutectic Al-Si cast alloys. The results showed that the wear rates of Al-Si alloys decrease with increasing silicon content. This could be due to the fact that higher amount of hard silicon present in high silicon content alloys restrict the dislodging of the mating surface material. Wear is high in unrefined and unmodified specimens and least in refined and modified specimens. The improvements in properties observed in the present studies are mainly due to the structural differences between the refined, modified or both refined and modified over just cast Al-Si alloys.

Next the machinability (cutting forces and surface roughness) characteristics of Al-Si cast alloys (cylindrical rods) using conventional lathe under dry environment with constant feed rate (0.1 mm/rev), cutting speed (226 m/min) and depth of cut (0.4 mm) for un-coated and polished CVD diamond coated turning inserts were taken up. Surface roughness of machined alloys under different conditions were evaluated using R_a (μm) and R_z (μm) parameters with the help of surface roughness tester (Mitutoyo SJ-301, Japan) as per ISO 1999 standards. The results suggest that, the combined addition of refiner and modifier to Al-Si alloys show improved machinability and good surface finish. Results also suggest that the cutting forces were high for un-coated insert. In contrast, the cutting forces for polished CVD diamond insert were substantially low. Such low cutting forces for polished CVD diamond insert could be from poor affinity of diamond for non-ferrous materials. Surface roughness values, R_a and R_z for machined surface produced by un-coated insert was observed to be high. But surface roughness of the workpiece produced by the polished CVD diamond insert was very low. Interestingly diamond polished insert continued to give a glossy surface till 12-14 min of machining after which it started giving few tear marks on the surface. All the alloys were cast in a graphite mould surrounded by fireclay brick (slow cooling). Hence further improvement in the mechanical properties, dry sliding wear behaviour and machinability can be expected for corresponding fast cooled alloys.

Key words: Refinement; Modification; Al-Si alloys; Al-Si-Cu alloys; Mechanical Properties; Sliding Wear; Machining; Surface Roughness.