Investigations on Aluminium Silicon Carbide Composite Spur Gears for Light Duty Applications

ABSTRACT

The focus of the manufacturing industry is on the development of newer materials to face the upcoming global challenges in providing safe engineered materials with specific and well defined properties. Composite materials constitute one of the favourable material zones for tomorrow‟s sustainable future through identification of materials with higher strength to weight ratio. Statistics reveal composite produced in India as equivalent to approximately 3% of the world wide output and 6% of Asia‟s output. The use of composites is only 3.6 % in automobile and 10% in aerospace industries. Therefore, finding some alternative material for automobile and aerospace applications to accelerate the Indian composite industry is imperative. An attempt has been made to develop light weight industrial components with required properties using composite materials.

Gears are the most important mechanical components because of their capability for transmitting motion. The gears applied in industries come in diverse weights and sizes. The applications are extensive, from textile loom gears to gears used in the aviation industry and to gear boxes for the elevator industry. Identification of light weight materials in components which are subjected to high force and stresses, such as gears for power transmission is still a challenging task.

Only a few researchers are currently working in the area of composite gears. According to a literature survey, their focus is on Fiber Reinforced Polymers (FRP) composite gear manufacturing and performance testing. It has become an important topic of concern in the international arena. Hence, this research work is focused on manufacturing and mechanical testing of Metal Matrix Composite material (MMC) spur gears. Aluminium Silicon

Carbide particulate (Al/SiC_p) composites have higher wear resistance, good strength and high heat conduction compared to other MMCs, leading to a higher concentration on practical applications. Hence, this research work focuses on the development of Aluminium Matrix Composite (AMC) materials for spur gear manufacturing. An intense survey of various gear manufacturing processes shows the sand casting followed by machining and powder metallurgy process having high adaptability in the development of spur gear and testing specimens using aluminium matrix composite materials.

The metal matrix spur gear blanks and test specimens were developed through stir casting process using Al-Mg and Al-Mg/ (Gr+SiC_p) materials. Magnesium and silicon series of aluminium alloy (Al6061) were used as a metal matrix of MMC material. The addition of magnesium to aluminium alloy improves the wettability between the aluminium matrix melt and SiC_p reinforcement material. The sample spur gears were manufactured using Al-Mg with 5 wt. % of SiC_p by stir casting and machining. Some defects were observed during machining due to the uneven distribution of SiC particle and poor wear resistance. Hence, the vortex method was applied by efficient stirring action for obtaining uniform distribution of SiC particles. Graphite (Gr) was also added as reinforced material before stirring considering its lower density than that of aluminium alloy. The material preparation with graphite resulted in reduction in defects and provided good finished spur gear and test specimens. The different compositions of AMC materials were prepared by varying the weight % of SiC_p as 0, 5 & 10 and using different grain size of SiC_p as 10 µm, 35 µm & 65 µm. The Brinell hardness test, tooth bending strength test, Charpy impact test, sliding pin on disc wear test and dynamic gear wear test were carried out to verify the effect of addition of SiC_p. The results confirmed that Al-Mg/ (Gr+SiC_p) materials have higher mechanical and wear characteristics than of Al-Mg material.

The Al/SiC_p spur gears were prepared by varying the weight percentages of SiC_p as 0%, 5%, 10% and 15% using powder metallurgy (P/M) process. Two powders of sizes SiC (35µm and 65µm – average diameters) and zinc stearate lubricant were applied. The gears had undergone the minimum bending strength test, hardness test and density test statically. The load carrying capacity of gears showed Al/SiC_p composite gear as suitable for making power transmission gears. The bending strength, hardness and density of the materials are closely associated with densification factor, compact pressure, presence of SiC content and particle size of SiC. These property variations also reflect the same results obtained through stir casting method.

The three dimensional tooth sector with rim thickness was modelled as per the selected module and face width, which were developed using stir casting and powder metallurgy. Static stress analysis and contact stress analysis were applied for C45 steel and Al/ 10 wt. % SiC_p gears, considering higher mechanical properties than with other compositions. Stress distribution showed the adequacy of smaller face width of Al/SiC_p gear for taking up the same load of larger face width of steel gear based on the factor of safety considerations. But, a deformation of 20 mm face width steel gear was lower than 20 mm face width Al/SiC_p gear. Hence, the face width was increased within 3 to 5 times of circular pitch for obtaining a minimal displacement for Al/SiC_p gears. The contact stress variations showed Al/SiC_p gear has lower contact stress than steel material. The conclusion from the numerical investigation is that, the light weight Al/SiC_p MMC material for gears provides a better performance than steel gear material.