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Effects of T6 heat treatment on mechanical, abrasive and erosive-corrosive wear properties of eutectic Al−Si alloy

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Abstract: The abrasive and erosive-corrosive properties of eutectic Al−Si (LM6) alloy were studied. Microstructural features of the alloy were altered by controlling the T6 heat treatment parameter, and their influence on hardness, strength and elongation, and response of the samples in erosion-corrosion and abrasion conditions were studied. Characteristics of the Al−Si alloy samples were compared with those of Al conventionally used in agricultural machineries. Fabrication of a typical component using the Al−Si alloy was also explored in order to understand the feasibility of using the alloy system for the envisaged applications. The study suggests the response of the samples in different conditions to be greatly influenced by parameters like chemical composition, microstructural features and applied load, traversal distance and test environment. The performance of even the as cast Al−Si alloy is far superior to that of the conventional Al samples, while the T6 heat treated Al−Si alloy shows improved performance. Accordingly, the as-cast as well as T6 heat treated Al−Si alloy has potential for applications in agriculture as a replacement for the conventionally used Al.
Key words: Al−Si alloy; heat treatment; abrasion; erosion; corrosion

1 Introduction

Sowing refers to broadcasting of seeds into tilled soil at an optimum depth and distance. One of the popularly used machines for sowing and metering seeds and fertilizers is known as seed-cum-fertilizer drill. Fluted roller is an external force-feed device used in the mechanical system for uniformly dropping the desired amounts of seed and fertilizer (like urea and diammonium phosphate) into the field during the sowing operation. This becomes a critical component of the sowing machinery system and usually is fabricated by casting scrap Al in the name of 'commercial Al' into shape in the Indian subcontinent [1]. It was suggested that severe pitting damage occurs in the Al alloy component due to the presence of bicarbonate, chloride, copper salts and alkali hydroxide in the surrounding media and is comparatively more prone to corrosion by chemical attack of the fertilizer [2,3]. The mentioned factors cause the component to loose its dimensional accuracy, resulting into improper metering of seed and fertilizer, mechanical damage to the seed being processed, inter-row variation of seeding and non-uniform placing of fertilizer, thus adversely affecting the efficiency and crop yield [4]. Poor strength and high susceptibility of the conventional component material to abrasive wear and erosion-corrosion encountered during operation appear to be responsible for the poor performance of the component.

Al−Si alloys have widely been used as wear resistant materials in different engineering applications. They are somewhat lighter than Al and exhibit good castability characteristics, and wear and corrosion resistance [5−7]. Binary eutectic Al−Si alloys like LM6 are hard with fairly good strength properties. Their response to heat treatment remains limited to morphological modification of eutectic Si particles [8]. Further, their better wear and corrosion resistance and relatively lower cost than other Al−Si alloys present them as an effective substitute to soft and weak Al with a wide application potential in the agricultural sector. It may be mentioned that alloying Al with Si imparts a significant improvement in the casting characteristics because of low thermal coefficient of expansion. Si also makes electrolytic potential of aluminum more positive in solution that is responsible for the improvement in corrosion resistance [5]. The high hardness of Si particles [9] imparts wear resistance to Al and renders the Al−Si alloys immune to intercrystalline attack in most rural,

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industrial and marine environments as structural components [6]. Shrinkage and gas porosity during solidification of Al−Si alloys are appreciably reduced [10] in view of improved fluidity imparted to the alloy system by Si. Eutectic Al−Si alloys possess the highest fluidity [11]. However, despite great potential, the possibilities of using Al−Si alloys have not been explored in agricultural applications to the best of our knowledge, where components like fluted rollers are conventionally fabricated by unorganized sectors using commercial Al with poorly defined composition and characteristics. Also, since erosion-corrosion and abrasion are quite frequently encountered by the agricultural components in operation, characterization of their response in such conditions becomes essential to effectively assess their capability. Heat treatment of binary Al−Si alloys, which essentially belongs to the category of non heat treatable version [12], and a study of its influence on the response of the alloy system makes it interesting from academic and technical standpoints. Optimization of heat treatment parameters like temperature and duration of treatment becomes another important aspect of concern that greatly controls the behaviour of materials.

In view of the above, an attempt is made in this study to examine the response of an eutectic Al−Si (LM6) alloy vis-a-vis the conventional Al used for agricultural applications in erosive-corrosive and abrasive conditions. The effects of parameters like ageing duration, applied load, traversal distance, test duration and environment are also investigated on the wear response of the samples. The influence of ageing duration during T6 heat treatment, thereby bringing about morphological changes in the eutectic Si particles, is also examined on hardness, tensile elongation and strength of the Al−Si alloy. The end objective of this investigation is to identify a material with improved quality and performance over the conventional Al that could have potential for use as agricultural machinery components like fluted rollers of a seed-cum-fertilizer drill used for sowing purposes.

2 Experimental

2.1 Sample preparation

Cylindrical (20 mm in diameter and 150 mm in length) and disc shaped castings (120 mm in diameter and 6 mm in thickness) of experimental Al−Si (LM6) alloy and conventional Al were prepared by liquid metallurgy route using cast iron moulds. The composition and density of the alloys are shown in Table 1. In order to explore the feasibility of making components, different assembly elements like feed cup, feed roller and feed-cut-off (Fig. 1) of fluted roller (sowing) system were also cast using metallic moulds and CO_2-silicate hardened green sand core.

Table 1 Composition and density of experimental Al alloys

Al alloy	Composition/%				Density/
	Al	Cu	Si	Fe	($g\cdot cm^{-3}$)
Conventional Al sample	Bal.	1.2	2.5	0.8	2.78
Eutectic Al−Si alloy (LM6)	Bal.	0.1	11.2	0.6	2.69

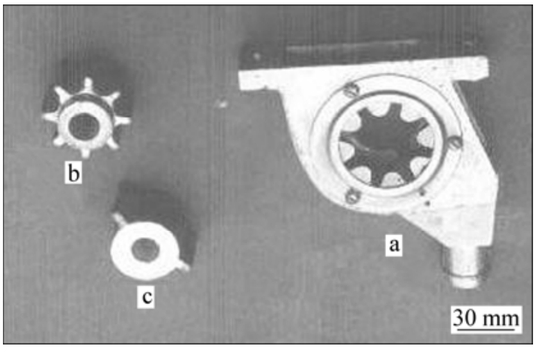

Fig. 1 Near net shape casting of fluted roller of Al−Si (LM6) alloy: (a) Feed cup; (b) Feed roller; (c) Feed cut off

2.2 Heat treatment

The Al−Si alloy was subjected to T6 heat treatment involving solutionizing followed by artificial ageing. The samples were solutionized at 525 °C for 3 h and quenched in water at ambient temperature. Ageing was carried out at 195 °C for 3−11 h. The aged samples were cooled in air to room temperature.

2.3 Abrasion tests

High stress abrasion tests were carried out on 35 mm×40 mm×3 mm rectangular specimens using a abrasion tester (Suga, Japan). The test essentially involves to-and-fro motion of the samples loaded against an abrasive medium. An abrasive paper fixed on a rotating metallic wheel served as the abrasive medium. The tests were carried out at the applied loads of 3 and 7 N while the abrasive employed was 180 grit (the corresponding particle size being 80 μm) SiC emery paper. Traversal distances adopted were 400, 800 and 1200 cycles corresponding to linear distances of 26, 52 and 78 m, respectively. Test arrangement was such that, by the time the specimen completed one to-and-fro movement/cycle, the abrasive wheel rotated one step forward enabling fresh abrasive surface to come in contact with the sample. Further, the wheel took one complete rotation by the time the specimen completed 400 to-and-fro movements/cycles. Each test was initiated using fresh abrasive medium, meaning thereby that fresh abrasive established contact with the sample during the first 400 cycles only and that the used abrasive was employed to abrade the specimen surface subsequently in tests involving more than 400 cycles. Metallographically