Effects of Rapid Preheating and Solution Heat Treatment on Mechanical Properties of AA2618 Forged Samples

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Abstract — **The microstructural and mechanical characteristics of rapid radiation heating and convection gas-fired heating on AA2618 forged samples have been studied. The rapid heating obtains refinement in grain size. The mechanical properties are greater in the AA2618 samples of rapid radiation heating.**

Keywords-rapid radiation heating, convection heating, AA2618, forging

I. INTRODUCTION

Forging is a metal forming process used to produce large quantities of identical parts, as in the manufacture of automobiles, and to improve the mechanical properties of the metal being forged, as in aerospace parts or military equipment. The process is typically performed by preheating the metal to a desired temperature before it is worked [1]. Aluminium alloy 2618 (AA2618) is a heat treatable Al-Cu-Mg-Fe-Ni forging alloy developed for high temperature applications especially in the manufacture of aircraft engine components [2]. The presence of stable intermetallic particles (such as aluminide particles of the phase Al_9FeNi helps to control grain size and impede dislocation movement [3].

Currently in the domestic industry, aluminum alloys are heated for forging with a wide variety of equipment: electric furnaces, muffled gas furnaces, oil furnaces, induction heating furnaces, fluidized bed furnaces, and resistance heating furnaces.

The objective of this paper was to investigate the application of an infrared (radiation) heating technique to aluminum 2618 alloy forgings and subsequent heat treatment operations. The mechanical and metallurgical characteristics were studied and compared with that of forgings heated in electrical furnace.

II. EXPERIMENTAL PROCEDURE

AA2618 alloy billets of 63.5 mm diameter and 150 mm long were rapid heated in an infrared furnace of capacity. The infrared furnace consists of two halves: an upper half carrying an array of tungsten halogen quartz lamps and a lower half with a drop-down arrangement used to load specimens into the furnace. The upper and lower halves are made of water-cooled stainless steel plates with firebrick lining. Thermocouples were placed on the surfaces of AA2618 alloy billets. Power was increased in 10% increments, and the time and temperature profiles were recorded with a multi-channel data acquisition system. To determine the effects of infra red heating on the metallurgy of this alloy, a comparative study was carried out convection electric furnace. The chemical composition of aluminium 2618 alloy billets is given in Table-1.

The flowchart of various operations carried out in this work is shown in figure 1. The forging and solution heat treatment temperatures were in accordance with AMS 2772 specifications. The times required for the billets to reach the desired temperatures by the two heating methods were given Table-2. The rapid solution heat treatment is shown in figure 2.

Table-1: Chemical composition of AA2618

Material	Element (wt.%)						
	Si	Fe	Cu	Mg	Ni	Ti	Al
2618	0.18	1.19	2.34	1.59	1.05	0.07	Remainder

Table-2: Heating practice

Heating method	Forging temperature, 425^0C	Solution heat treatment temperature, 530^0C
Radiation heating	20 min	25 min
Electric furnace heating	100 min	120 min

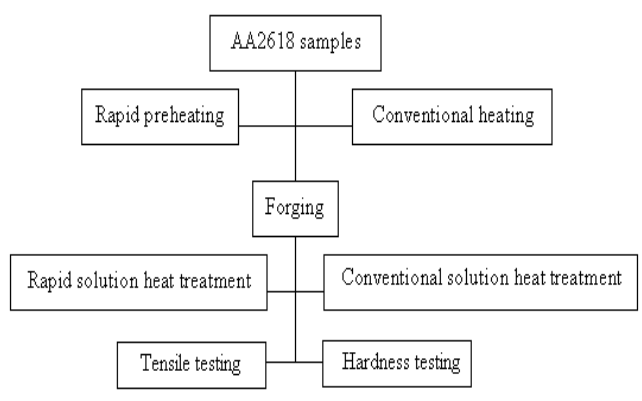

Figure 1: Flowchart of various operations

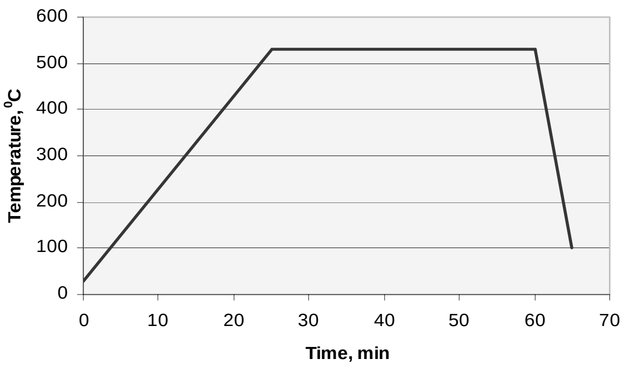

Figure 2: Rapid solution heat treatment

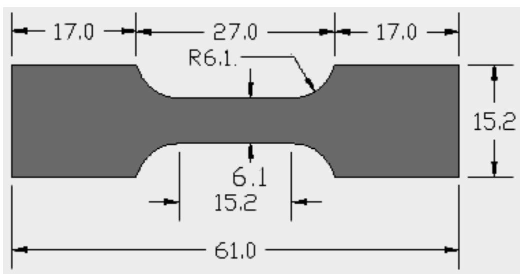

Figure 3: Shape and dimensions of tensile specimen

The forging dies were heated to 350^{0}C using infrared insert heater prior to forging. Forging of preheated billets at 425^{0}C was carried out using a hydraulic press with an upset ratio of 2:1 and a strain rate of 0.5 s^{-1}. Temperatures during radiation heating of the billets prior to forging and during solution heat treatment were monitored.

The microstructures of characterization of AA2618 before forging and after forging were examined using Madras metallurgical optical microscope. The Rockwell hardness tester was used to measure the hardness of the forged specimens. The Rockwell hardness test method was carried out with a hardened steel ball having diameter 1.6 mm. a minor load of 10 kgf and major load of 100 kgf. The forged samples were machined to get specimens for tensile test. The shape and dimensions of the tensile specimen are shown in figure 3. The computer-interfaced UTM (Universal Testing Machine) was used for the tensile test. The specimens were loaded hydraulically at a crosshead speed of 0.02 mm/s. The loads at which the specimen has reached the yield point and broken were noted down. The extensometer was used to measure the elongation.

III. RESULTS AND DISCUSSION

Each experiment was repeated on three samples to find mechanical properties. The average of three readings is reported.

A. Effect of rapid preheating on AA 2618 samples before forging

Optical micrographs on transverse sections of AA2618 samples are shown in figure 4. The specimens were etched with a mixture of 2 g of NaOH, 4 g of Na_2CO_3 and 94 ml of water. Both specimens exhibit similar microstructures, characterized by intermetallic particles distributed in a recovered polycrystalline α matrix. The presence of stable intermetallic particles (such as aluminide particles of the phase Al_9FeNi was found Energy-dispersive X-ray spectroscopy (EDS) analysis in both samples (figure 5). The specimens, which were heated rapidly to the preheating temperature of forging, appear to reveal a slightly higher volume fraction of intermetallic particles as compared to convectional heated samples. There are instances where the magnesium-rich samples in the convectional preheated AA2618 samples (figure 6). The convectional preheated AA2618 samples had more time to form magnesium rich intermetallic particles. The intermetallic particles during convection heating undergo spherodization and partially dissolve.

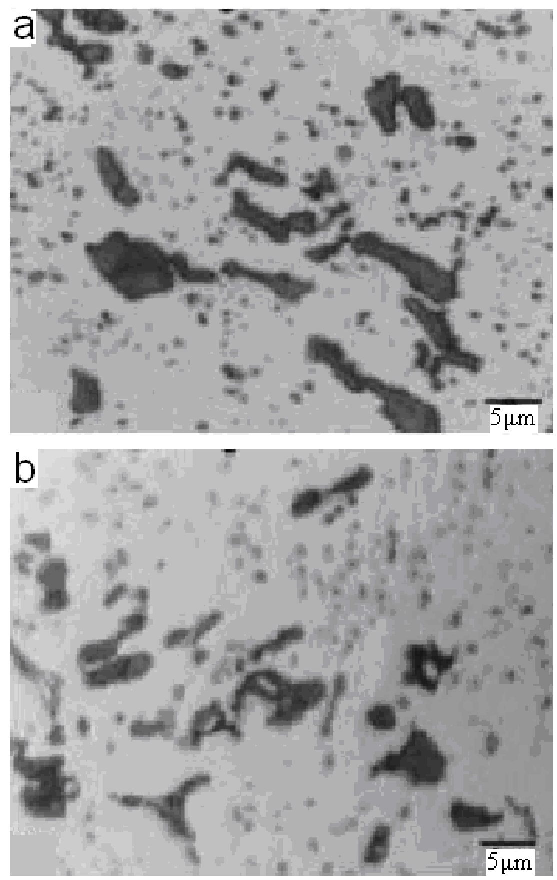

Figure 4: Micrographs of AA2618 samples under rapid (a) and convectional (b) heating

B. Effect of rapid preheating on AA 2618 samples after forging

The preheated AA2618 samples were forged at 425^{0}C and water quenched. Due to deformation, the intermetallic particles have become round and uniformly distributed in the α-matrix. The rapidly preheated samples appeared to have more intermetallic particles than the convectional preheated samples (figure 7).

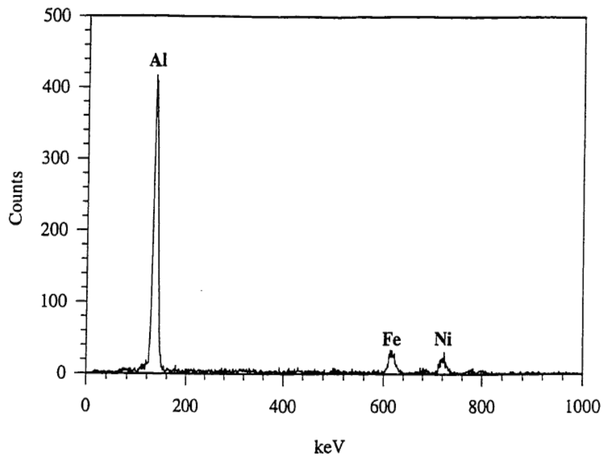

Figure 5: Energy-dispersive X-ray spectroscopy analysis for identification of intermetallic aluminide particles

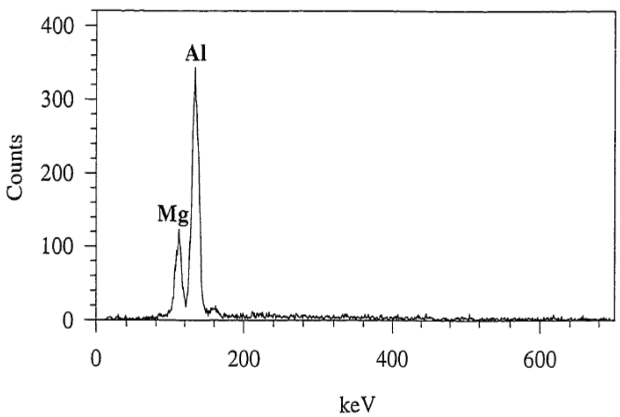

Figure 6: Energy-dispersive X-ray spectroscopy analysis for identification of magnesium-rich particles

C. Effect of rapid solution heat treatment after forging

Barker's reagent was used to reveal the grain boundaries. The specimens of rapid heating and convection heating exhibited equiaxed spheroidal grains indicative of full recrystallization during the solution heat treatment (figure 8). The specimen processed rapid heating exhibits much smaller grains than the convectional heated specimen. This resulted because the shorter exposure to high temperature of rapid heated specimen left more intermetallic particles with less particle coarsening in the α-matrix.

D. Effect of rapid heating on the mechanical properties

The mechanical properties of the specimens are given in Table-3. Hardness tests were conducted at the centre of transverse cross-section of the forgings. Tensile test specimens were cut longitudinally from the centre of the forging samples. The mechanical properties rapidly heated specimens are greater than those of convectional heated specimens. The improvement in mechanical properties was due to grain refinement and due to the retention of larger amounts of solute elements in the matrix during the short heat treatment time.

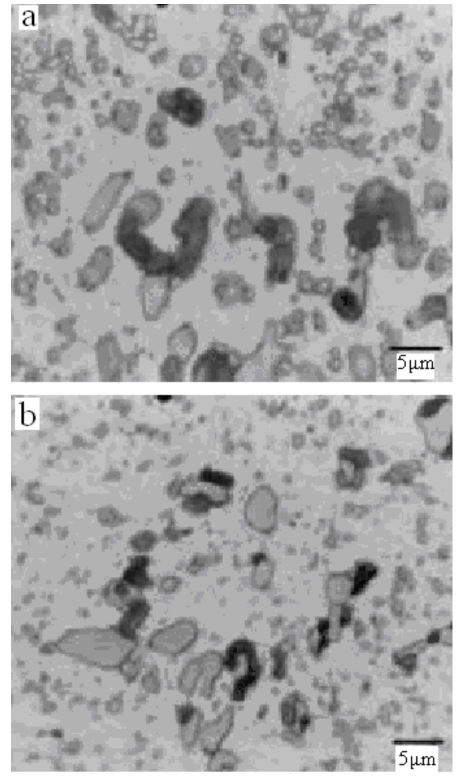

Figure 7: Micrographs of AA 2618 samples after forging under rapid (a) and convectional (b) heating

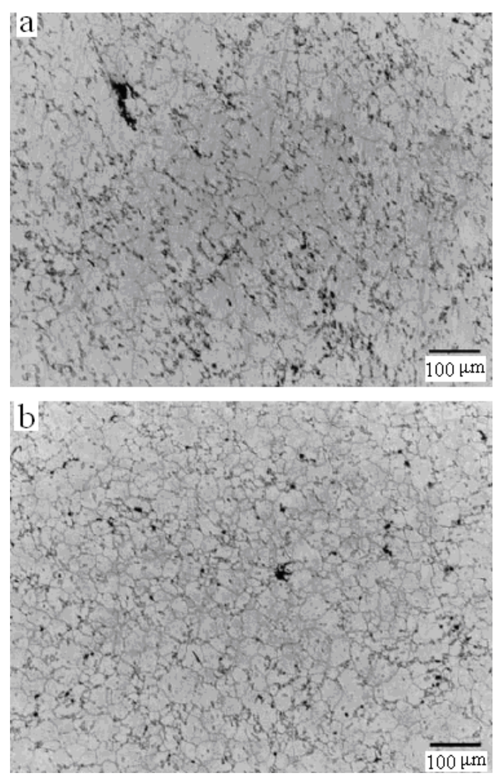

Figure 8: Micrographs of AA2618 after solution heat treatment under rapid (a) and convectional (b) heating

Table-3: Mechanical properties of forgings

S.No.	Hardness, HRB	Yield strength, MPa	Ultimate tensile strength, MPa	Elongation, %
Rapid heating	67.7	270	370	14
Convection heating	59.5	266	345	13

IV. CONCLUSIONS

The rapid heating obtains refinement in grain size. The mechanical properties are improved. The rapid heating results in more productive in terms of time than the convection gas-fired furnace heating.

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