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The Impact of Gamma Radiation on Aluminum Alloy Thermal Conductivity Alumina Composite 6063

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A B S T R A C T

The thermal conductivity of aluminum alloy 6063 alloy reinforced with alumina particles was studied. Aluminum alloy 6063 alloy matrix composites reinforced with varying weight percentage of alumina particles (0, 3, 5, 7) were prepared using the stir casting technique. Under normal circumstances (before to irradiation), the thermal conductivity tests were performed for every weight percentage. Because of the reinforcement material, we observe that the values of thermal conductivity drop as the weight % increases. Following exposure to gamma rays emitted from cesium, which has a half-life of 30.04 years and an emitted energy of 662 KeV, tests of thermal conductivity are conducted. When compared to thermal conductivity readings under normal circumstances, the results indicate a drop in thermal conductivity levels following irradiation. The thermal conductivity of the developed composites was analyses and compared with the matrix alloy. The experimental results showed that the composition ratio of reinforcement and gamma radiation influenced the structure of aluminum alloy 6063 alloy through homogeneously dispersed within the matrix and point defect. It can be leading to destroyed in thermal conductivity.

1 Introduction

Because aluminum alloy matrix composites (AMCs) are widely used in a variety of life disciplines and industries, including electronics, conductivity, automotive, aerospace, defense, and nuclear, the sun and other environmental factors are exposed to these compounds. The impact of gamma radiation on aluminum alloy composite materials must be investigated because of their significance in our daily lives. The employment of composite aluminum alloy materials in modern times represents a substantial change in these materials properties since numerous attributes led to widely use in various fields. Low fabrication costs, durability, low density, high specific stiffness and strength, improved high temperature properties, low thermal expansion, resistance to moisture and chemicals, corrosion resistance, shapes and sizes, and high surface strength are some of these attributes [1]. For researchers to create and apply these materials in their practice areas, it is essential to investigate their mechanical and physical characteristics. Simply put, aluminum alloy composite materials are systems created by combining two or more elements according to certain guidelines to create new materials with unique mechanical and physical characteristics that are drastically different from those of their parent material. Currently, both ionizing and non-ionizing radiation have an impact on composite materials. Ionizing radiation causes significant changes in the characteristics of composite materials. When radiation enters an aluminum alloy composite, it significantly alters the matter's composition by changing the arrangement of atoms and molecules. Because of the interaction between the photons and their absorbent material, the composite material's structure is altered by the effect of photon radiation. The target's atomic number and photon energy determine the sort of reaction. Scientists have been inspired to build specialized software for the design and analysis of composite materials as well as to test the majority of their properties without using conventional methods due to the growing use of composite materials in the development of sophisticated computer science and software. The composition and structure of certain composites, such heterogeneous materials, can have a significant impact on heat conductivity. The majority of materials used in thermal engineering are heterogeneous, meaning that their thermal physical characteristics change depending on their direction and position [2, 3, 4]. Because of its superior mechanical qualities, which include low density, high hardness, high strength, and outstanding chemical stability, the usage of aluminum oxide (Al_2O_3), silicon carbide (SiC), boron carbide (B_4C), and magnesium oxide (MgO) reinforced aluminum alloy matrix has grown. It may result in a decrease in the aluminum alloy matrix's thermal conductivity [5]. MMCs and AMCs can be produced using a variety of techniques, including additive manufacturing, powder metallurgy, chemical vapor deposition, liquid infiltration, stir casting, and spray deposition [6].

This research is carried out to determine the thermal conductivity property pre-and to post exposure Gamma which emitted from the cesium source (Cs^{137}) for the aluminum alloy 6063- Al_2O_3 composites at different weight percentage (0, 3, 5, 7) Al_2O_3 and study the effect of these rays in fixed time (2 hours) on these properties. The effect of these radiations varies depend on the mixed of the materials with these rays.

2 Materials and Methods

2.1. Materials

The material of interest in this investigationis commercial aluminum alloy, 6063, as matrix with density 2.7g/cm^3 and micro-alumina particles as the reinforcements were used to produce the composite material under this study. The nominal chemical composition of aluminum alloy, 6063 as shown in Table 1.

Table 1. Chemical composition of AA 6063.

Elem. W%	Mg	Si	Fe	Mn	Ga	Cu	Cr	Zn	Ti	Al
Min	0.45	0.4	0.15	0.02	-	-	-	-	-	Bl
Max	0.51	0.46	0.19	0.04	0.02	0.01	0.01	0.01	0.014	

In the current research, alumina with particle size ranging from 70-230 μm and density 4 g/cm^3 was used, which was supplied from the Arab Republic of Egypt the nominal chemical composition of alumina as shown in Table 2.

Table 2. Chemical composition of alumina.

Element	CaO	TiO_2	FeO_2	Others	Balance
Wt%	1.2	1.6	0.4	0.03	Al_2O_3

2.2 Sample Preparation

2.2.1 Composites samples preparation

Stir cast metal matrix composites Al6063/ Al_2O_3 were used for the study. The Al6063 alloy scraps were heated in separate tube furnaces till 800 °C as shown in Figure (2.1b) with using of a steel container. After complete melting of the alloy, the temperature of the molten alloy was kept at a temperature of 800 °C± 10 °C, which is higher than its liquidus temperature by about 140°C to allow the complete dissolution of the alloying elements. Alumina powder was used in this investigation as reinforcement, and then treated with addition different amounts of alumina in weight percentage such as 0, 3, 5 and 7 respectively. After addition of alumina, the melt was manually stirred with a steel rod for 10 minutes. After mixing manually, the composite slurry was returned to the furnace, reheated to 800 °C about 20 minutes. The molten slurry was manually stirred for 10 minutes for wettability and homogenized distribution of reinforcement particles. The melt mix was casted into permanent a cylindrical steel die, which was made according to certain standards with a diameter of 100 mm and a thickness of 30 mm, as shown in Figure (2.1a), until the solidification process was complete at room temperature. According to many researchers [7], the composite samples were fabricated using the stir composite casting method as shown in Figure (2.3a). The stir composite casting technique is a process of melting metal matrix alloy with reinforcement using continuous stirring means to ensure wettability and uniform distribution of reinforcement in the melt, and instantly pouring into the permanent mould for solidification.

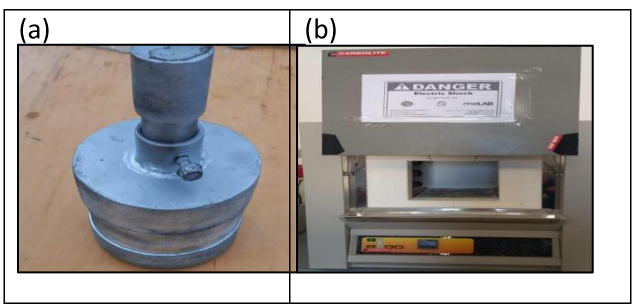

Fig. 2.1 permanent a cylindrical steel die (a), tube furnaces (b).

2.3 Gamma Ray Sources

The sources of gamma rays used in this study are cesium, which has a half-life of 30.04 years and an emitted energy of 662 KeV. Figure 2.2 shows the gamma-ray spectrometer that was utilized in this study

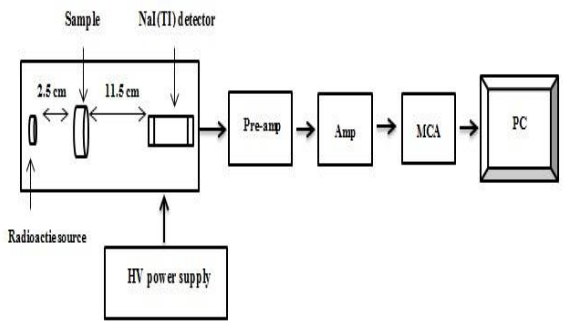

Fig. 2.2**:** Schematic view of the experimental setup**.**

2.4 Gamma radiation's interaction with matter

As it travels through materials, gamma radiation interacts with them in a variety of ways. Compton scattering, pair creation, and the photoelectric effect are the three primary mechanisms. The energy of the incident photon determines the likelihood of each of these interactions. The Compton Effect is dominant at low energies, while pair formation is dominant at high energies. Similar to rapid electrons, gamma rays can cause point flaws. It is extremely unlikely that a direct interaction between gamma rays and atomic nuclei in crystal will result in the displacement of an atom. The secondary fast electrons created by the photoelectric effect, the Compton scattering of gamma rays, or the formation of electron positions pairs at high gamma ray energies are responsible for the majority of faults. The three procedures mentioned above result in the overall absorption cross section of gamma rays. The likelihood that each of these occurrences would occur may be determined by Evans and a few others. Through the lattice, Frenekel flaws are uniformly formed. The vacancies in the solid are mobile at finite temperatures, especially above -173 °C. They combine with the solid or with impurities, as well as from defect complexes; to obtain lower energy levels in the forbidden gap .Atomic nuclei are minuscule in crystals. The majority of flaws are created by secondary fast electrons that are created by the photoelectric effect, Compton scattering from gamma rays, or electrons that it is challenging to analyze the problem theoretically, particularly because there is a dearth of information regarding the precise values of the capture cross sections. By measuring electrical conductivity and the Hall Effect, one can investigate the quantity of defects created by hard radiation as well as the energy levels of these flaws. There are two known elements of how radiation interacts with matter. A significant portion of an incident's energy is used for electronic processes (excitation and ionization), which causes brief or transitory disruptions in the material that fade away as soon as the radiation source is removed. Atoms are displaced inside the solid lattice as a result of atomic processes using the remaining incident optical energy. Damage is defined as the percentage of these displacements that last for 10^3 seconds at room temperature [8].

2.4 Irradiation of the Specimens

After the composite samples were prepared by stir casting techniques as shown in Figure (2.3a), the next experimental step was the irradiation process, four composites samples with weight percentage (0, 3, 5, 7 Al_2O_3) without irradiation and Four composite samples with same percentage were subjected to irradiated for 2 hours. The irradiation processes were carried out in the laboratories of the Department of Physics. The distance between the irradiated source and the samples was fixed at 2.5 cm. In the final experimental step, both radioactive and non-radioactive samples were tested in order to verify the effects of irradiation in the laboratories of the Faculty of Mechanical Engineering, Omar Al-Mukhtar University.

2.2.2 Samples for Thermal Conductivity

Three cylindrical billets were cut and machined from the same position for all composite samples with the dimension of thickness 30 mm by 25 mm diameter as shown in Fig.2.3(b) and prepare according to used procedures development for aluminum alloys. Investigated specimens were obtained under different condition with adding the (0, 3, 5, 7) wt. % Al_2O_3 particles.

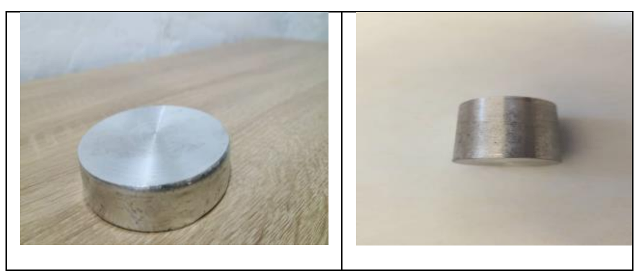

Fig. 2.3 composite sample (a), cylindrical billets for thermal conductivity(b).

Twenty-four groups of samples, three billet from each weight percentage (0, 3, 5, 7 Al_3O_2) without irradiation and another three billet from the same percentage were subjected to irradiated for 2 hours with Cs ^{137} in the presence of oxygen with a constant 662 kV power source.

2.2.3 Thermal Conductivity test

The amount of heat that is conduction-transferable via a unit cross-sectional area of material when the temperature gradient exits perpendicular to that region is known as thermal conductivity. The rate of heat transport within a substance is indicated by its thermal conductivity value. In particular, thermal conductivity is temperature dependent and rises marginally with increasing temperature, while this difference is tiny and frequently insignificant. Thermal conductivity test of cylindrical billets samples using thermal conductivity measuring apparatus as shown in Fig.2.4

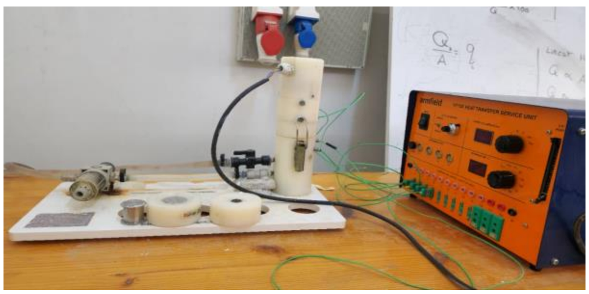

Fig: 2.4 Thermal conductivity measuring apparatus.

For each set of readings the derived results are under the following headings:-

Heat flow (power to heater) Q = VI (Watts) (1)

Cross sectional area $A = \pi r^2$ (m^2) (2)

Temperature difference across specimen

$$\Delta T = T_{Hotface} - T_{Coldface} \quad (3)$$

The thermal conductivity value is calculated using the following equation [9]:

$$k = \frac{Q\,dx}{A\,dt} \quad (4)$$

Where Q– heat transfer rate (Watt), k – conduction heat transfer coefficient (Watt/m °C), A – cross-sectional area of the test object (m^2), dT – temperature difference (K), and d x – length of specimen. In this test used the calculated value of Q =41.6 Watt. Fig. 4 shows thermal conductivity test equipment. This instrument is used to measure thermal conductivity capacity. The coefficient of thermal conductivity k is a constant that relates the heat flux Q to the temperature gradient dt/dx and the unit is Watt/m °C or Watt/m.K.
Thermal conductivity tests are carried out using the following thermal conductivity measuring instruments. A test specimen measuring 25 mm in diameter and 30 mm thick is inserted under load between two similar specimens of materials of known thermal properties. The test takes place, the ambient temperature is 20 °C and. At equilibrium conditions, the thermal conductivity is obtained from the average temperature gradient in each specimen and the thermal conductivity of the reference material. By using the one-dimensional conductivity equation, referring to equations (4), the thermal conductivity can be calculated.

3. Results and Discussions

3.1 The effect of Al_2O_3 content on the thermal conductivity of aluminum alloy composite

The practical results of the thermal conductivity of the aluminum alloy- alumina composite billets are shown in Figure 3.1. A decrease in thermal conductivity property with increasing aluminum oxide content was noticed. However, there is a significant change in the thermal conductivity compared to that of 0% and 7% aluminum oxide billets. This indicates that the alumina in aluminums alloys dissolve in the matrix or exist in a precipitated state, which hinders the movement of dislocations. This, in turn, enhances mechanical properties and scatters electrons, reducing thermal conductivity. The used aluminum alloy- alumina significantly impaired the thermal conductivity. This minimizes the detrimental effect on thermal conductivity to satisfy industrial demands for lowered thermal conductivity. Many authors have studied the thermal conductivity of aluminum alloys. Many parameters influence the thermal conductivity such as chemical composition; structures, heat treatment and Temperature are the critical parameters affecting the thermal conductivity of alloys. In the literature, the value of thermal conductivity of pure aluminum is reported to be 237 [$W \cdot m^{-1} \cdot K^{-1}$]. Alloying elements and ceramics particles such as aluminum oxide reduce this value, whether they are dissolved in the solid solution or precipitated as a secondary phase. The literature indicates that the higher the strength properties of Al alloys composite in the as-cast state, the lower the thermal conductivity [10].
The rapid decrease in thermal conductivity in the weight percentage range of alumina from 0% to 7% can be explained by the change in structure caused by the reinforced phase. Addition of ceramic particles such as Al_2O_3 can led to decrease the thermal conductivity. muhammad et al. [11], who investigated the thermal conductivity of aluminium alloys -Al_2O_3 composite materials, reported that the thermal conductivity of this composite decrease with increase Al_2O_3 content. The higher the weight percentage (0%, 3%, 5%, and 7%), the lower the thermal conductivity values of all samples before irradiation. We find that the weight of the base material affects the thermal conductivity; whenever their quantity is higher, the thermal conductivity coefficient was high. The maximum thermal conductivity values are at the weight percentage (0%)

because there is a large amount of conducting base material present, and the thermal conductivity will be higher than other fractions that contain a base material in large quantities. We find that the weight of the base material affects the thermal conductivity; whenever their quantity is higher, the thermal conductivity coefficient was high, as shown in figure 3.1. The lowest thermal conductivity values are at the weight percentage (7%) because there is a small amount of insulating reinforcement material present, and the thermal conductivity will be higher than in the other fractions that contain a base material in large quantities. Also reported by many investigators.[10,11].

3.2 Gamma radiation's impact on aluminum alloy composites' thermal conductivity

The aluminium alloy alumina composite billets samples were exposed to gamma rays at energy of 662 KeV for period of two hours at room temperature. The practical results are shown in Figure 3.1 which illustrates the effect of gamma irradiation on the thermal conductivity of composite materials. From this figure, we notice that the thermal conductivity decreases for all samples when these samples are exposed to gamma rays for two hours. Gamma rays can produce point defects such as Frenekel, Schottky defect and vacancies. The probability of an atom being displaced by a direct interaction between gamma rays and atomic nuclei in crystal is very small. Most defects are formed by the secondary fast electrons produced as a result of the photo electric effect, the gamma rays Compton scattering or/and the electrons positions pairs creation pairs creation formed at high gamma ray energies.

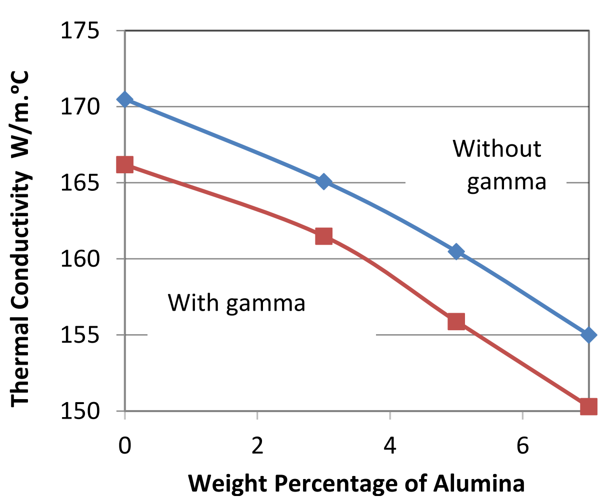

Fig. 3.1 Thermal conductivity of the aluminum alloy alumina composite.

The total absorption cross section of gamma rays is determined as a result of the above processes. Evans and some others defects could probabilities of occurrence for each of these events. Such defects are produced uniformly through the lattice, bonds between the atoms of the composite and its sliding movement, and this leads to the possibility of absorbing part of the energy and then increasing the energy required for breaking. The gamma rays will penetrate the sample into the interior, which leads to an increase in defects. The thermal conductivity values of all billets are decreased with the increase of the weight percentage of alumina (0%, 3%, 5%, and 7%) at exposed to gamma rays for period of two hours at room temperature. Due to the presence of an insulating reinforcement material (Al_2O_3), the thermal conductivity will be higher than in the other fractions that contain a matrix material in large quantities. Therefore, we find that the weight of the matrix material affects the thermal conductivity; whenever their quantity is higher, the thermal conductivity coefficient was increased, as shown in figure (3.1). The maximum thermal conductivity values are at the weight percentage (0%) and the minimum thermal conductivity values are at the weight percentage (7%) due to this. The exposure of aluminum composite material to Gamma radiation with high energy leads to produced point defects, leading to detrimental in thermal conductivity values. Which is agreed with the findings of the researchers[2, 3, 4, and 8].

Conclusions

The thermal conductivity of the investigated composite without gamma radiation ranges from approximately 155 to 170.5 [Watt/m. K°] at ambient temperature and shows an increasing trend as a function of decrease in weight percentage of alumina. The step decrease in the thermal conductivity of aluminum alloy6063- alumina composite is due to the precipitation of reinforced phase. This indicates that the alumina particles dissolved in in aluminums alloys matrix or exist in a precipitated state, enhances scatters electrons. It can be lead to reduce the thermal conductivity of Aluminum alloy 6063 composite.

The thermal conductivity of the Aluminum alloy 6063-alumina composite after exposed to gamma radiation at two hours shows that the decreased in thermal conductivity. Moreover, the performed research proves that the thermal conductivity decreases for all samples. The interaction of Aluminum alloy 6063- alumina composite material with Gamma radiation at high energy leads to produced point defects, leading to detrimental in thermal conductivity.

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