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IN-SITU PHASE TRANSFORMATION AND MICROSTRUCTURE OF REINFORCED ALUMINIUM MATRIX COMPOSITES (AA-6061 T6+NICR NP) WITH AND WITHOUT TIC NANOPARTICLES

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Abstract

Because of its exceptional qualities, aluminium composites are frequently employed in aircraft applications. Aluminium alumina composite was manufactured in-situ using the AA-6061 T6 matrix alloy and 3 %age, 6 %age (Nichrome) powder. Optical metallography, Image Analysis, and micro hardness tests were used to assess the in-situ composites. The specimens then liquid preheated at 550 °C for 3 hours and then aged at 180 °C for 7 hours to improve the durability in mechanical characteristics. In comparison to the as cast samples, the heat-treated samples showed significantly higher mechanical properties. AA-6061 T6 matrix composite reinforced with in-situ alumina particle with TiC was also studied for grain refining. The Al-4.5 % Ti-1.5 % C master alloy has been shown to be an effective grain refiner.

Keywords*: In-situ, Nichrome Nanoparticle (NiCr Np), Metal Matrix Composites (MMC), TiC Nanocomposites.*

Introduction

Composites are composed of two or more constituent materials [1] that have considerably diverse mechanical, chemical, or physical characteristics yet stay distinct and separate on a macroscopic scale inside the final structure. The matrix of a metal matrix composite is often a lighter metal such as aluminum, magnesium, or titanium, and it offers a complaint support for the reinforcement [2, 3]. The matrix has reinforcing material inserted in it. The reinforcement is not necessarily employed for simply structural purposes (i.e., reinforcing the composite), but it may also be employed to alter physical qualities like wear resistance, friction coefficient, or thermal conductivity [4].

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Metal Matrix Composites has become one of the most significant innovative materials [5], now a days more interesting candidate for their high mechanical characteristics. Because of their high specific modulus and strength, as well as excellent fatigue and creep resistance, aluminum-based metal matrix composites have gotten a lot of interest as building components in the aeronautical, automotive, and transportation sectors [6].

Aluminum matrix composites, for example, are frequently utilized because of their strong strength also at extreme temperatures, fracture toughness, lower densely populated, high thermal conductivity, and great abrasion resistance [7]. In addition to traditional metal processing techniques, the emergence of diverse metal matrix composite systems has led to the creation of innovative analysis methods.

Since many studies have looked at MMCs, they have discovered that reducing the size of the reinforcement improves the characteristics. Some of the disadvantages of metal matrix composites, such as low ductility, poor machinability, and decreased fracture toughness, may be solved by scaling down the particle size in metal matrix composites to nanoparticles. The inclusion of nanoparticles (NPs) in metals is predicted to result in considerable improvements due to recent developments in creating particles smaller than 100 nm. A nano composite is made up of two phases, at least one of which is nanoscale (less than 100 nm) in one dimension [8].

The in-situ technique [9] is used to mix Nichrome particles (NiCr NP) into the aluminum melt. The interaction between matrix and reinforcement in in-situ processing is free impurity pathways. The products are relatively stable and devoid of impurities. The melt environment will also shield the particles from oxidation. In order to produce an effective load transfer mechanism in nanocomposites, a strong connection between in-situ particles and the metal matrix is required. Furthermore, the in-situ produced reinforcing particles are smaller and have a more uniform distribution in the matrix, resulting in higher mechanical characteristics than ex-situ composites [10-12].

The goal of this study is to build and analyze an AA6061 matrix composite by adding an oxide bearing compound like Nichrome to it (NiCr NP). Optical metallography, Image Analysis, and microstructure are used to analyze the produced composites. Furthermore, an AA6061 matrix composite reinforced with NiCr NP particles is investigated both with and without inclusion of TiC.

Methodology of Production

Materials selection

The composite is prepared with AA-6061 T6 (aluminum alloy-Temper 6) in this study. AA-6061 is a precipitation-hardening aluminum alloy with the main alloying components magnesium and silicon. Optical emission spectroscopy was utilized to verify the chemical composition, and the true composition of the alloy employed in this investigation is shown in Table 1. The matrix has the reinforcing material incorporated in it. As reinforcement, Nichrome (NiCr NP) powder is utilized. Furthermore, TiC, an Al-4.5 % Ti -1.5 % C master alloy, is employed as the grain refiner. In comparison to another master alloy, Al-4.5 % Ti -1.5 % C, the literature reveals that Al-4.5 % Ti -1.5 % C master alloy produces good results with the matrix alloy. Heated drops were decreased marginally with the addition of Al-4.5 Ti-1.5 C, but dramatically with the addition of Al-1Ti-3C. Due to massive $TiAl_3$ particles serving as strong connections during solidification, the inclusion of Al-5Ti-1C did not result in a reduction in warm drops.

Composite Fabrication Technique

Resistance-heated ovens were used for alloy treatment. Ingots of AA-6061 were accessible. The needed quantity of AA 6061 alloy was extracted out from ingots and deposited in the furnace heater, which already housed the crucible. The alloy reached the liquid state when such temperature reached 660 ℃ the alloy begins to deteriorate at this temperature, whereas fluidity increases at 710 °C. The appropriate quantity was introduced to balance it due to the lack of magnesium content (as confirmed by optical emission spectroscopy) in AA 6061. The wettability of the molten was improved by adding 1% wt. magnesium to the solution. The alloy then degassed using hexa chloro ethane (C_2Cl_6) degassing tablets at an elevated temperature of around 710 °C the melt had been used to dissolve these 0.7 wt. % tablets. And the alloy was kept at 710°C, after which the warmed (300°C) Nichrome powder (x %wt, x=3%, 6%) was poured at a rate of 1 gram per minute using the composite synthesizing set up. For the in-situ generation of reinforcement Al_2O_3 by the interaction between matrix Al and NiCr NP, the composite was permitted to agitate for about 20 minutes[13, 14]. The Al-4.5 % Ti-1.5 % C (TiC) master alloy was also introduced (0.5% wt.) with the reinforcement inserted composite to enhance the composite structure and increase its efficiency. Finally, the liquid metal reinforcement and alloy combination was put into a preheated (150°C) frame. The difference strength was validated by the in-situ composite that was manufactured. Figures 1 depict the mixing process throughout composite preparation.

Table 1. Component of elements in AA-6061 matrix alloy

Element	**Aluminum**	**Magnesium**	**Silicon**	**Ferrum**	**Copper**
Weight %	97.2	1	0.6	0.40	0.275
Element	**Chromium**	**Nickel**	**Titanium**	**Manganese**	
Weight %	0.195	0.125	0.125	0.080	

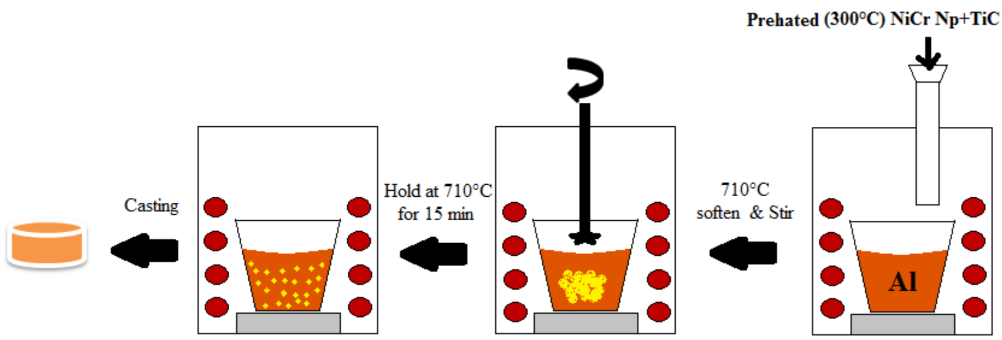

Fig. 1. Molten Aluminium in situ technique

Results with Discussion

Analyzing the chemical composition

Table 2 shows the addition percentages of TiC in the in-situ prepared composites that were evaluated to use an optical emission spectrometer. The results clearly demonstrated that when the amount of NiCr NP nanoparticles increases, the Al concentration falls as the Cu increase intensity. Furthermore, as compared to non-TiC composites, TiC has been proven to increase the value of Ti in composites.

Microstructural characterizations of a specimen

The specimens' microstructural characteristics were investigated using an optical microscope with image analysis.

Characterization of an AA 6061+ X NiCr composite (X=3%, 6%) In the absence of TiC

A metal matrix composite using AA 6061 aluminum alloy as the matrix and aluminum particulates as reinforcement was created by in situ interaction of NiCr with heated AA 6061 without TiC. Figs. 2 and 6 illustrate the microstructures of the in-situ composite generated by applying 3% NiCr and 6% NiCr, respectively, in the absence and non-additive of TiC under etching circumstances to detect the grain boundary.

Table. 2. The addition of TiC and grains sizes in prepared composites

Elements	A Specimen in the absence of TiC	A Specimen in the presence of TiC
Aluminum	96.5 at 3% of NiCr NP	96.4 at 3% of NiCr NP
	93.0 at 6% of NiCr NP	94.5 at 6% of NiCr NP
Titanium	0.02 at 3% of NiCr NP	0.045 at 3% of NiCr NP
	0.03 at 6% of NiCr NP	0.044 at 6% of NiCr NP
Silicon	0.75 at 3% of NiCr NP	0.8 at 3% of NiCr NP
	1.0 at 6% of NiCr NP	0.8 at 3% of NiCr NP
Cupper	1.6 at 3% of NiCr NP	1.8 at 3% of NiCr NP
	3.5 at 6% of NiCr NP	3.2 at 6% of NiCr NP
Manganese	0.09 at 3% of NiCr NP	0.09 at 3% of NiCr NP
	0.1 at 6% of NiCr NP	0.1 at 6% of NiCr NP
Magnesium	1.0 at 3% of NiCr NP	0.8 at 3% of NiCr NP
	1.2 at 6% of NiCr NP	0.8 at 6% of NiCr NP
Chromium	0.13 at 3% of NiCr NP	0.75 at 3% of NiCr NP
	0.12 at 6% of NiCr NP	0.13 at 6% of NiCr NP
Ferrum (iron)	0.13 at 3% of NiCr NP	0.13 at 3% of NiCr NP
	0.8 at 6% of NiCr NP	0.73 at 6% of NiCr NP
Silicon	0.75 at 3% of NiCr NP	0.8 at 3% of NiCr NP
	1.0 at 6% of NiCr NP	0.8 at 6% of NiCr NP
Nickel	0.05 at 3% of NiCr NP	0.04 at 3% of NiCr NP
	0.04 at 6% of NiCr NP	0.07 at 6% of NiCr NP

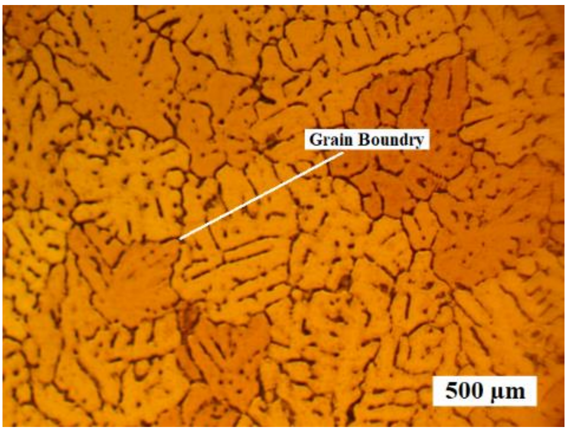

Fig. 2. AA 6061+ 3 NiCr NP In the absence of TiC

In the structure, we can see alumina particles and the creation of grain boundaries. The generated intermetallic may also be seen in the microstructures. The production of alumina as well as the stages formed, such as $NiAl_2$, has been observed. Grain results for the composite in the absence of TiC are calculated in Fig. 4, and the grain size is mostly about 100 µm-350 µm.

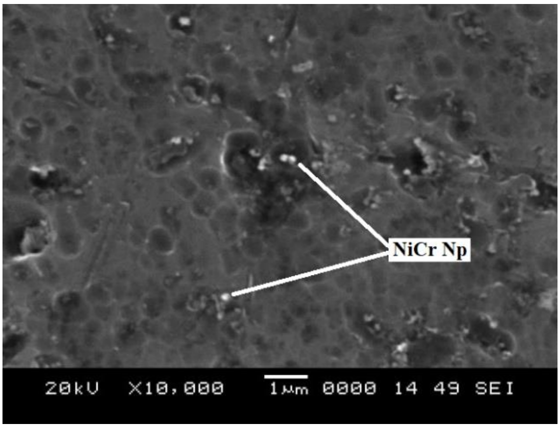

Fig. 3. AA 6061 + 6 NiCr NP in the absence of TiC

Characterization of an AA 6061+ X NiCr composite (X=3%, 6%) In the presence of TiC

The grain refiner Al-4.5Ti-1.5 C master alloy (TiC) was introduced with % wt. to manufacture the 0.02 % Ti within the in-situ composite that has already been manufactured in order to minimize grain size and boost characteristics. Fig. 5 shows the microstructures of an in-situ composite containing 3% NiCr and TiC.

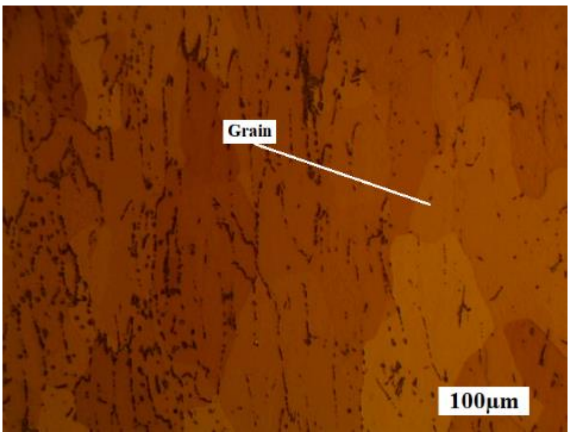

Fig. 4. AA 6061+ 3 NiCr In the presence of TiC

The TiC will diminish grain size from 80 µm-350 µm to 90 µm-100 µm as illustrated in the Fig. 4. The grain boundaries of the grains are visible at a high magnification of 20X in the figures. Figures 7 illustrate the grain boundary of the composite casting sample, which has a grain size of roughly 30-60 µm, and also shows copper and pure Nichrome powder, which will increase the strength and hardness of the alumina particles generated. If the amount of NiCr was higher, it may be feasible.

Fig. 5 illustrates the ring formed by the stage $NiAl_2$ inside of the composite during solidification. It is also possible to construct the shape that is plainly evident. The qualities of the casting may alter as a result of these two processes. The TiC created by adding Al-4.5Ti-1.5C functions as an excellent grain refiner for aluminum alloys, and the grain refinement is greatly enhanced when compared to castings in the absence of Al-4.5Ti-1.5C. In the absence and presence of Al-percent Ti-1C addition in the microstructure, this difference is clearly visible. The grains produced average 90 micrometers in length.

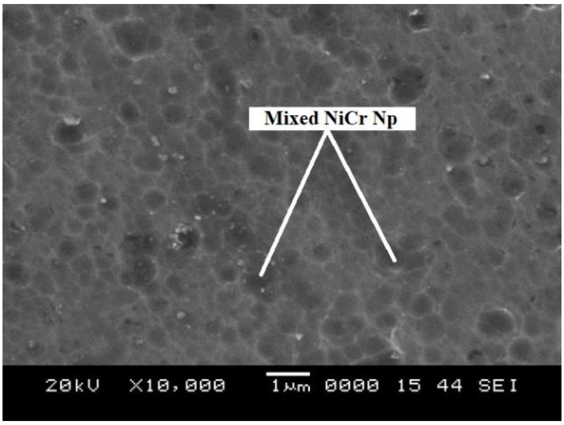

Fig. 5. AA-6061 + 6 NiCr In the presence of TiC

Refinement of grain boundary and its enhanced values

The additions of TiC master alloy were the key factors in reducing grain size. We can enhance the qualities of the composite casting by lowering the grain size. The image analyzer coupled to the Leica optical microscope was used to determine the grain sizes. The average grain size values recorded while capturing microstructures using a Leica optical microscope with image analyzer are listed in Table 3. The addition of TiC refines the grains and lowers their sizes, as shown by the results.

Table. 3. The addition of TiC and grains sizes.

% age of Nanoparticles	Grain size of sample in the absence of TiC	Grain size of sample in the presence of TiC
3% NiCr Nanoparticles	230μm	95μm
6% NiCr Nanparticles	190μm	50μm

The addition of TiC to the composite resulted in a significant reduction in grain sizes, as seen in Fig. 6. This is mostly due to Titanium carbide nucleation. The grain size was initially 230 m and was decreased to 95 m with a little quantity of TiC. The grain size was also lowered by 3.8 percent wt. NiCr and TiC with a 50 m value. Hardness will rise as particle size decreases.

The physical characteristics of metals are influenced by the size, shape, and arrangement of phases, as well as particle size. Precision microscopes with a magnification of roughly 500 X and a measuring precision of +0.4 microns were applied to calculate the indentations. Differences of +0.3 micrometers may generally be corrected to the same investigator. The composite was subjected to a Vickers hardness test to determine the hardness of the various stages.

Table 4 shows the hardness values of composite samples under heat treated (fluid processed & time toughened) and as cast settings for different test samples. The link between hardness levels and sample type is also shown in Fig. 7. The samples were solution heated for 3 hours at 550°C before being aged for 7 hours at 180°C.

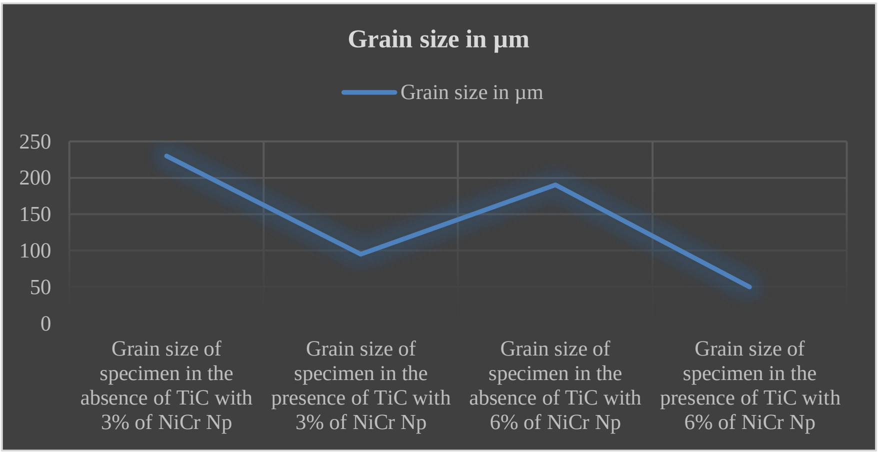

Fig. 6. Comparison of grain sizes

Table 4. hardness values of specimen at different conditions.

Specimen data	HV values at casting	HV values at heat treated
Absence of TiC with 3% NiCr	101	150
Presence of TiC with 3% NiCr Np	138	164.3
Absence of TiC with 6% NiCr Np	115.2	148
Presence of TiC with 6% NiCr Np	119.7	150.6

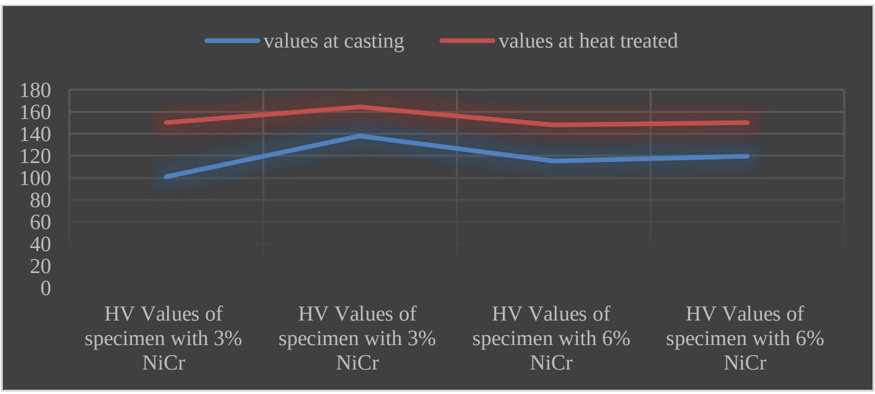

Fig. 7. Hardness values of specimen at different conditions

The findings reveal the production of very fine precipitates as well as an increase in strength and hardness. The inclusion of the master alloy Al-4.5Ti-1.5C enhanced the hardness of AA-6061, allowing tiny intermetallic particles to be released evenly throughout the melt and function as nucleating sites. These stable intermetallic particles serve to boost hardness and strength. As a result, the hardness results calculated from micro hardness testing show that adding Al-4.5Ti-1.5C master alloy to the materials would improve their qualities and raise their hardness value. The heat treatment procedure, along with solution treatment after aging treatment, raises the hardness value to 25 Hv better than before. The following table show the hardness values of specimen at different conditions.

Conclusions

In situ fabrication of aluminum composite was accomplished.

The manufactured composite has the phases -Al_2O_3, Mg_2Si, $NiAl_2$, NiCr, and Ni. The mechanical characteristics of the castings are improved by the stages, stages, and - Al_2O_3.

The insertion of 0.4 wt.% TiC to the composite (through a master alloy addition of Al-4.5Ti-1.5C) decreases grain size and raises hardness values from 141Hv to 166Hv.

By nucleating particles, TiC serves as a grain refiner and raises the strength and hardness characteristics Hardening at 180°C for 7 hours.

When compared to samples that have not been aged, the hardness value following solution treatment is roughly 25Hv - 35Hv.

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