ISSN: 2641-1784

Research Article

Advance in Environmental Waste Management & Recycling

Effect of Alkali Hydroxide on the Properties of PTFE Graphite Bonded Aluminium Titanium Composite Sheet

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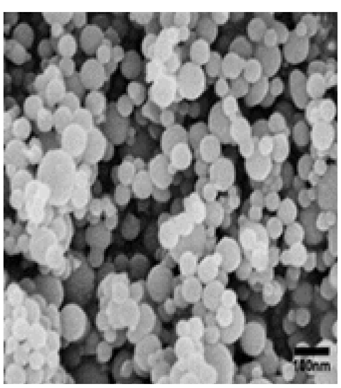
Submitted: 26 Sep 2020; **Accepted**: 03 Oct 2020; **Published**: 12 Nov 2020

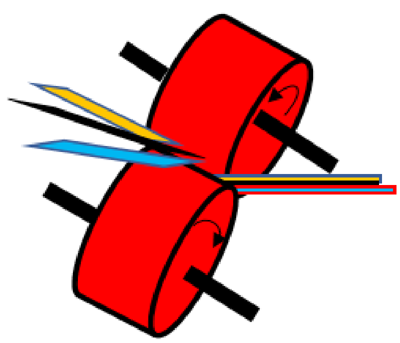
Abstract
This study focused on the effect of some alkali hydroxide on the properties of a composite sheet prepared by power spray coating of clean aluminium-titanium sheets with PTFE/graphite emulsion. The blank sheets were washed with hot water and dried at 80 °C for 5-6 minutes before power spraying of colorless polytetrafluoroethylene PTFE/graphite emulsion in perfluoro kerosene followed by hot-rolling under a pressure of 150-200 KPa at the temperature 50 °C higher than the melting temperature of the PTFE polymer (Du Pont). The obtained sandwich was sintered at 550 °C for a few minutes. Alkali hydroxide was added to the polymer emulsion before spraying. Results showed that temperature and time enhanced the extent of adhesion of the two metals to form a homogeneous composite metal sheet. Alkali hydroxide inclusion deteriorates the stability of the prepared sheet. The alkali effect was because PTFE is inactive material, Incompatible with molten alkali metals and alkali hydroxide. The disability of the alkali hydroxide to be incompatible with the polymer material experienced changes in its intrinsic properties. Alkali halides have insignificant effect. Alkali halides just displayed a filling in material.

Keywords: Al CTi, Aerospace sheet, Electroless deposit, Triple laminar metals.

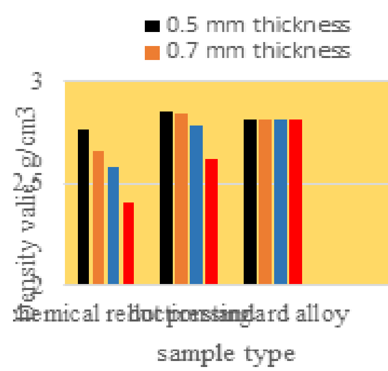
Graphical abstract



Al nanoparticles



Titanium nanoparticles



Density of the prepared samples

Introduction

Perfluorokerosene L
2-Methyl-2-butene

CAS: 513-35-9
Molecular Formula: C5H10
Molecular Weight: 70.13

The aerospace materials for use may be present in nature and used to the manufacturing the early aircraft. Aerospace materials are developed metal alloys used for aerospace applications or have come to prominent [1]. Development of materials for use in the aerospace application was to adopt materials such as Duralumin which means hardening of aluminium alloy(s) and scoring of this goal of new and/or unavailable properties. Aerospace science often requires very high performance such as mechanical or thermal properties. Materials engineering is rigid and an important norm within the aerospace application has been fully regarded. The international standard bodies maintain specifications for the materials and processes involved [2].

Engineers and academicians had performed extensive work for aeronautic materials improvement. The aerospace materials for use may be present in nature and used to the manufacturing the early aircraft. Such materials were also utilized after timber in wing structures and fabric and dope to cover them. The material quality was of utmost importance and so the timber would be of carefully selected. Standard specifications were this highly required for the proper selection, manufacture, and use of these materials. Specifications were then developed and updated with the cooperation of manufacturer's engineers or maybe government technicians and often with the assistance of university engineering departments.

Development of materials for use in the aerospace application was to adopt materials such as Duralumin which means, hardening of aluminium alloy(s) and scoring of this goal of new and/or unavailable properties. Many of these new materials were studied to report their new properties and how to beneficiate the best use of them. That work was carried out through the financial and technical help and/or supervision of national laboratories and research institutions aluminium for aluminium alloys for airframes and skin, and composites for structures and composites for structures. Some reporters predicted composite materials and aluminium metal may constitute the roost when it comes to aerospace innovation and similar updated structures [3]. On the other hand, Ibrahim et al reported the mechanical properties and fracture of Al-15 vol% B4C based metal matrix composites. It is a relatively low cost, especially when compared to aluminium or composites of aluminum alloys [4].

The aluminium producer Co, Alcoa, in 2013, for example, predicted around 6% more aluminium will be used in planes compared to 2011. The company, also claimed that the current fleet of airliners and military jets are the main users of aluminium, and newer designs continue to specify lots of this metal. It was reported that one of the largest passenger airliners in the world, contains 10 times the amount of aluminium used as compared to the less updated model of the airliner. Also, Boeing's 787 Dreamliner, is structured containing 20% aluminium alloy 7085 (by weight), which was relatively new [5].

Aluminium is alloyed with some nonferrous elements such as manganese, silicon, aluminium, magnesium, or zinc and antimony to further increase its strength. Cold working is a technique used to increase the strength of these alloys. However, some alloys are further strengthened and hardened by heat treatments. Aluminium matrix composites: (MMCs). These consist of metal alloys reinforced with fibers, whiskers, particulates, or wires. Alloys used as matrices to date are of aluminium, aluminium, magnesium and aluminium. For example, and according to NASA space Shuttle, 240 struts were made of aluminium reinforced with boron fibers.

The researcher reported the influence of some alloying elements on the microstructures and mechanical properties of aluminium alloys and aluminium alloy composites [6]. When oxidized, aluminium forms a hard, microscopic oxide protective coating from the environment. Al-Zn alloy 7075 is strong .as compared to steel. The alloy includes 5.6-6.1% zinc, 2.1-2.5% magnesium, and 1.2-1.6% aluminium. It is commonly produced in heat temper grade [7, 8]. With proper selection and placement of carbon fibers, the composites of aluminium can be stronger and stiffer than steel parts with similar thicknesses of 40 to 70% lightweight. The chemical resistance is much better than that of glass-reinforced composites. Particularly in alkaline medium. However, carbon composites are relatively brittle. They have no yield behavior and their resistance to impact is low [9].

Thermal characteristics of carbon fibers differ as compared to other materials. This property helps in making the design of structures with zero or very low linear and planar thermal expansion [10]. The following table 1 gives the comparing aerospace composites followed by precipitation as hydroxide using ammonium hydroxide solution. It was filtered and the hydroxide gel was reduced with ascorbic acid or hydrazine hydrate.
Table 1 shows the characteristics of different commercial graphite-polymer composites

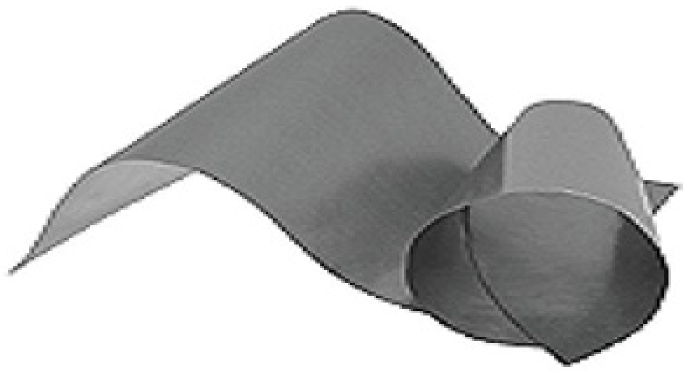
Table 1: The characteristics of different graphite-polymer composites.

Material Type	Nomenclature	Tensile strength, (Psi).	Modulus (Psi).	Strain (%)
Carbon/Epoxy	T300/934	245	20	1.0 – 1.2
	IM7/85517	400	24	1.62
	P75/934	135	44	0.2-0.5
	AS4/35016	100	10	1.0
	IM6/35016	330	23	1.5
Glass/Epoxy	Eggless/934	150-170	68	2.75
Kevlar/Epoxy	K49/7934I	80 -85	4	1.85
Carbon/PEE	M7/APC2	410	24	1.6
Carbon/Phenolic	FM5055	15-20	2.6-2.8	1.0-1.2

This paper aims to prepare a triple-layered aluminium-carbon-titanium sheet and characterize its properties for possible application in aerospace.

Experimental
Materials and Method

A polymer sheet doped with synthetic flake graphite fine powder measuring 80 x 200 mm and 0.2 mm in thickness was prepared according to the method given by Zhou et al under 100 kPa [11].



The graphite polymer sheet

The sheet was used for the electroless deposition of aluminium and aluminium metals. The plate sample was heated at 250 °C to get rid of any oil impregnate. The graphite sheet was punched with 2 mm-diameter hard chrome die with a spacing of 10 mm between the centers of two adjacent punches. The graphite plate was washed and dried at 110 °C for 4 h before storing in a horizontally mounted Perspex cell, 6 mm in thickness fitted with a lid. Fig 2 shows a schematic diagram of the graphite sheet

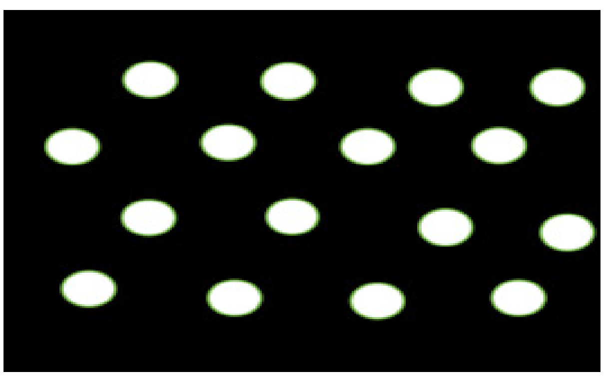


Figure 2: Schematic diagram of the graphite sheet.

Description of experimental procedure

Preparation of titanium metal was applied according to the method given by Badawy et al [12]. Graphite sheet was prepared according to the method described by Wang et al [13, 14].

Preparation of the triple-layer metal composite sheet

Samples were prepared by two alternative ways; the first was the chemical reduction of the metal ions and the second by hot rolling using hard chrome steel rolling machine. Aluminium, graphite composite and titanium sheets were rolled at 500 °C, the rolling process of the samples was repeated for 5 times.

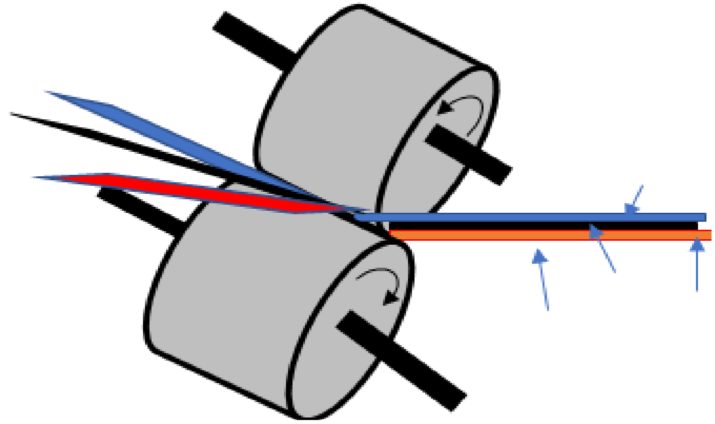


Figure 3: Assembly of the rolling device

Table 2: shows the properties of the chemicals used

chemical	source	Purpose	property
Nitric acid	SP.GR.1.18 (AR)	Leaching	ADWIC
	Min. assay 36 %	Process	Riedel- de Hein
	Fuming 69 %		ADWIC
H2SO4	H2SO4 95-97%		
	Extra pure		
HCl	SP.GR.1.18 (AR)		
Ca CO3	Green Egypt	Synthesis process	99.3,
EJSF2	Sigma Aldrich		1.6 um
Ca oxide			3.34 g/cm3, 1.57 um
NaOH	United Co.		reagent for analysis
Ammonium hydroxide	for chemicals & Med. Preparations		25 % Pure reagent for analysis
AgNO3 (Silver Nitrate)		Chloride ion determination	Pure reagent for analysis
distilled water		Chemical reactions	
Tap water		Other purposes	

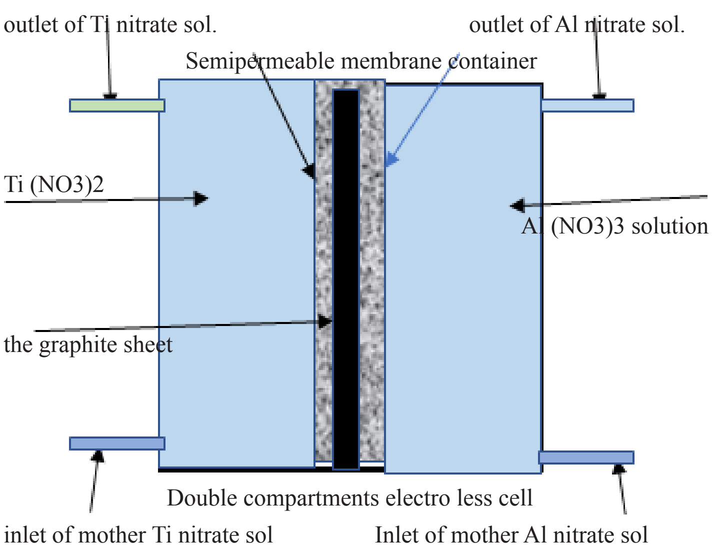


Figure 4: shows Schematic diagram of the test rig used in the first method.

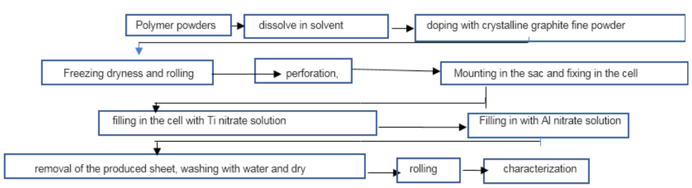


Figure 5: The experimental process flow sheet

Designation of the prepared samples

The following Table 3 shows the composition of the prepared samples. Hot pressing was carried out using chromium die steel at pressure s up to 105 KPa. Pressing was performed for triple pressings.

Table 3: Summary of the composition of the prepared samples.

Sam-ple	Chem-ical	depo-sition	mm	Hot rolling	Hot rolling KPa,	mm.
	Al	C	Ti	Al	C	Ti
1	0.23	0.1	0.20			
2	0.34	0.2	0.36			
3	0.80	0.2	0.55			
4	1.01	0.2	0.55			
5				0.18	0.1	0.20
6				0.52	0.20	0.40
7				0.85	0.20	0.55
8				1.1	0.2	0.55

Results

Fig. 1 shows the graphical abstract of this manuscript. It contains an image of the SEM assigned to the aluminium particles. A schematic diagram of the rolling equipment for the preparation of the triple layered sheet by mechanical rolling method. The graphical abstract also contains a figure of the effect of the method used for the preparation of the triple layered sheet on the density of the end product. Fig. 3 shows 3 an assembly of the rolling device used for the mechanical method for the preparation of the triple layered sheet. The graphite sheet is coated with a thin layer or film of a thermosetting adhesive on both sides to enable good adherence of the three layers together. Fig.5 shows the steps of the experimental process flow sheet applied in this work. Figs 6 through 8 show SEM images of the graphite-doped polymer sheet (Fig. 6); an image of Al particles (Fig. 7) and an image of the deposited titanium after 10 minutes (Fig. 8). It is seen that the graphite polymer sheet has some surface defects together with some minor punches. Particles of aluminium are ball-like spherical particles having an average diameter of 30=75 nm. In Fig. 8, titanium crystals have a top view square-shaped, but examination reveals that these crystals are decahedral,

Figure 6: SEM images of the graphite-doped polymer sheet.

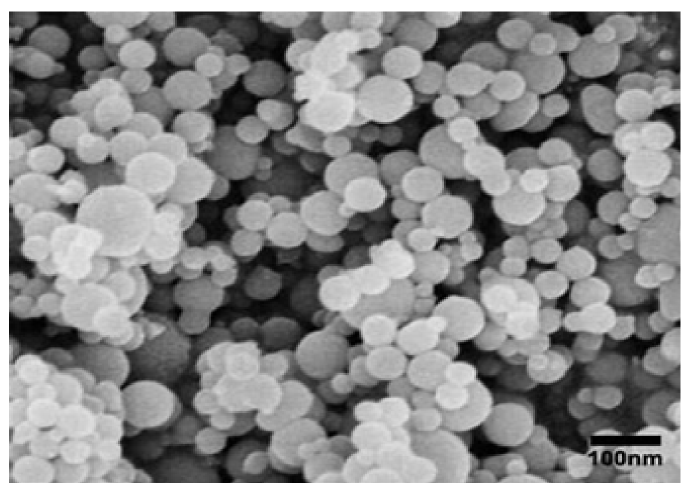


Figure 7: SEM image of Al particles.

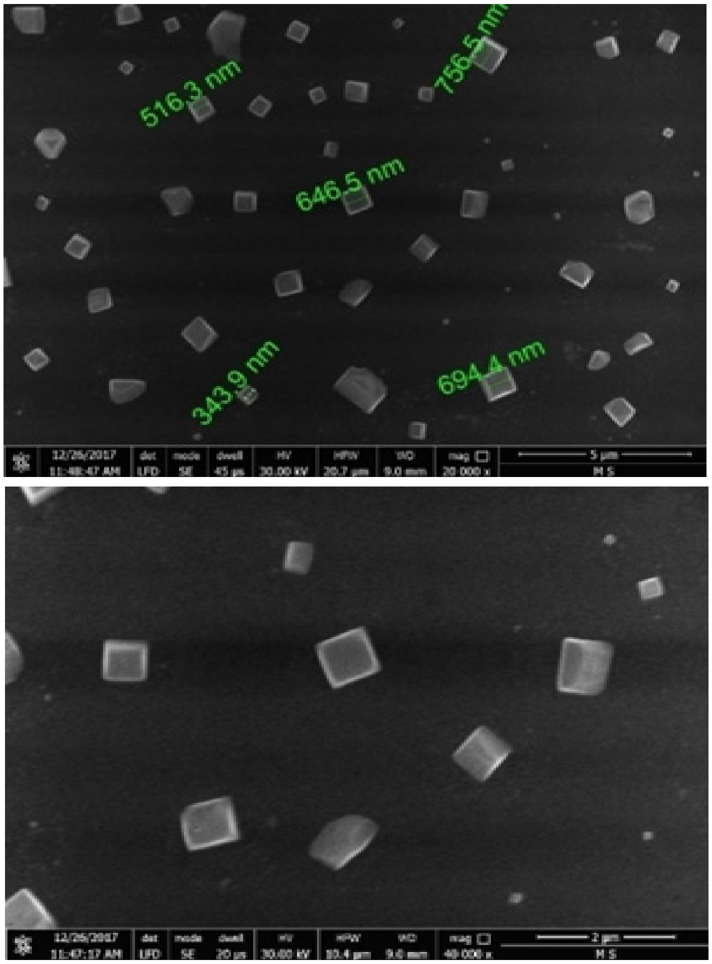


Figure 8: SEM image of the deposited Ti after 10 minutes of deposition.

Fig. 9 shows the effect of concentration of aluminium nitrate solution filling-in the electroless cell on the weight of the aluminium particles deposited on the graphite polymer plate for different times up to 12 hours. It can be seen that the weight of the deposited aluminium particles increased with the increase in both the aluminium nitrate concentration up to 5 M and the time of the electroless deposition process up to 12 h. The weight of the deposited aluminium particles per 1 square centimeter surface of the graphite polymer plate amounts to 0.32 g, 0.85 g, and 1.32 g with 3 M solution after 2 h, 6 h and 12 h respectively. The corresponding values determined with 5 M solution amount to 0.6 g, 1.8 g, and 2.35 g after 2 h, 6 h and 12 h, respectively.

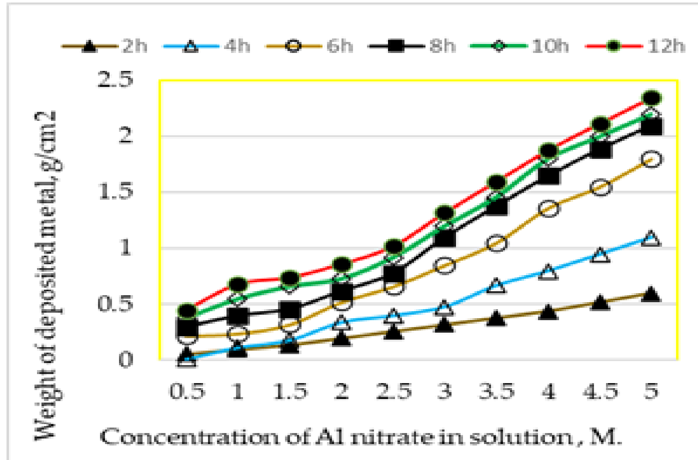


Figure 9: The effect of concentration of aluminium nitrate solution on the weight of the deposited Al particles.

Fig. 10 shows the effect of concentration of titanium nitrate solution filling-in the electroless cell on the weight of the deposited titanium particles. It can be seen that the weight of the deposited Ti crystals increases regularly with the corresponding increase of Ti nitrate concentration and time of electroless deposition.

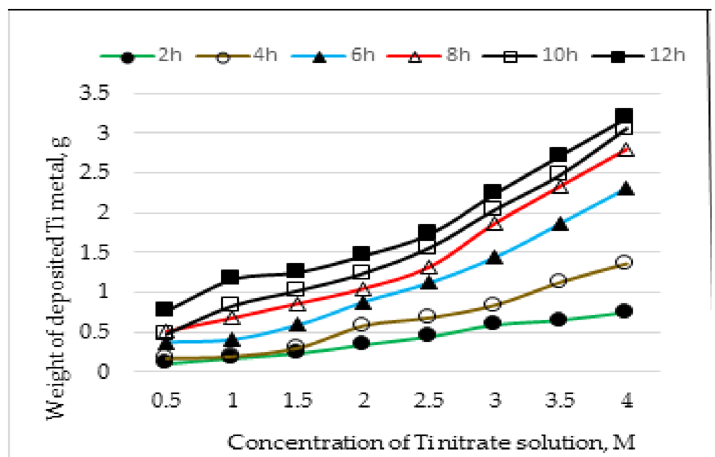


Figure 10: The effect of concentration of titanium nitrate solution in the electroless cell on the weight of the deposited titanium.

Fig.11 shows the effect of the deposited aluminium thickness together with the graphite polymer and the titanium metal (0.2 mm) on the density value of the obtained triple sheet samples. It can be seen that the density value of the triple sheet samples -prepared by the electroless deposition method- is lighter than the hypothetical density value. The density value of the triple sheet samples decreases with the increase in the thickness of the deposited aluminium up to 1 mm. On the other hand, the density value of the triple sheet, prepared by hot pressing of the three layers, is very close to the hypothetically calculated density.

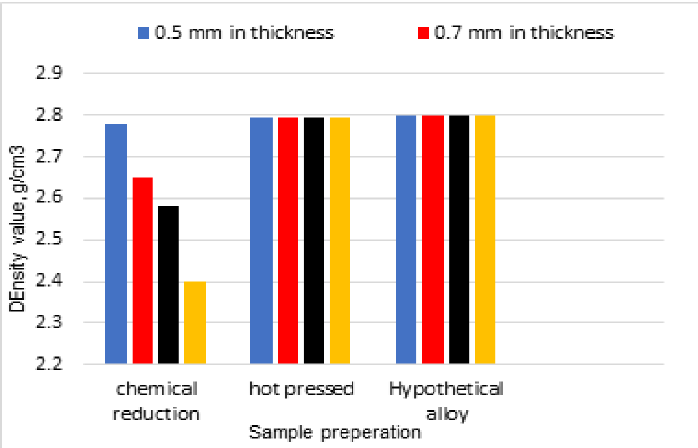


Figure 11: The density of the triple sheet prepared with different thickness of aluminium and constant thickness of titanium at 0.2 mm.

Fig 12 shows the density of the triple-layered sheet prepared with different thickness of aluminium and constant thickness of titanium at 0.2 mm. It is seen that the density value increases slightly with the increase in the thickness of the aluminium layer. Density attains a value of 2.55 g/cm3 with samples having about 0.38 mm aluminium in thickness.

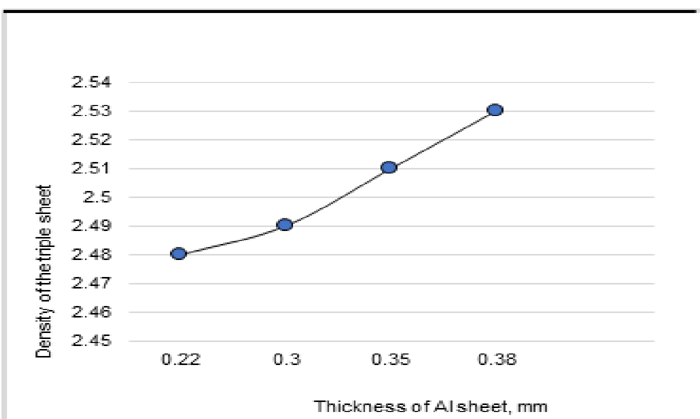


Figure 12: The density of the triple-layered sheet prepared with different thickness of aluminium and constant thickness of titanium at 0.2 mm

Fig. 13 shows the effect of the global thickness of the prepared triple sheet sample by hot pressing the three materials having an equal thickness on the density value. It can be seen that the density value displays the same trend as shown in Fig. 12, provided that the value of the density is comparatively higher.

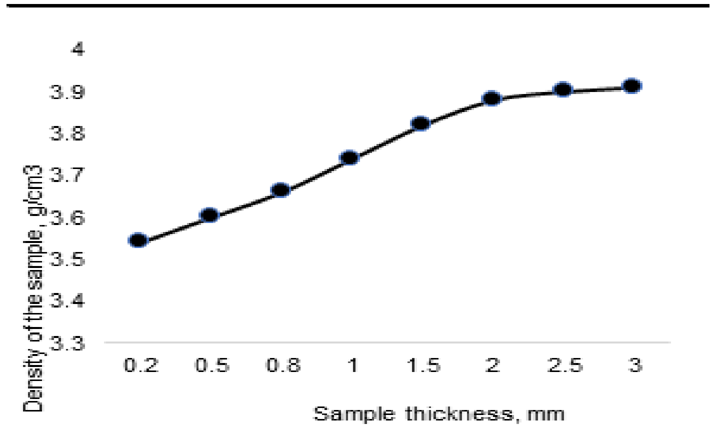


Figure 13: Of thickness of the prepared triple-layered Al-C-Ti samples.

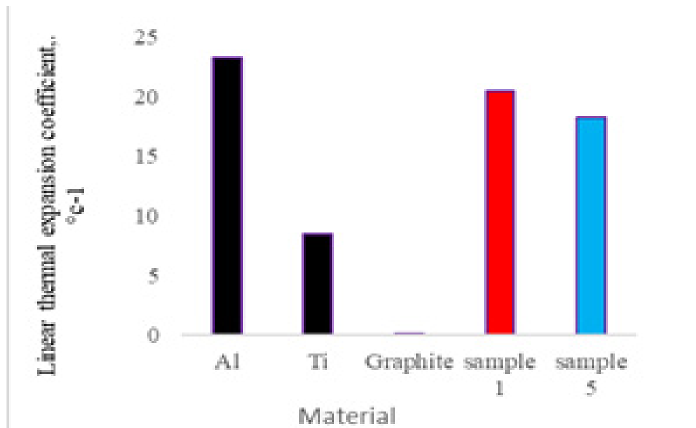


Figure 14: shows the linear thermal expansion coefficient (LTEC) of the prepared samples by the chemical reduction technique.

Fig.14 shows the linear thermal expansion coefficient (LTEC) of the prepared samples by the chemical reduction technique. It can be seen that the LTEC value increases in the order Al, Ti sample 1, sample 5 and graphite.

Table 4 shows the character of the finished samples of triple-layered Al-C-Ti sheets

Table 4: Characters of the finished triple-layered Al-C-Ti sheets.

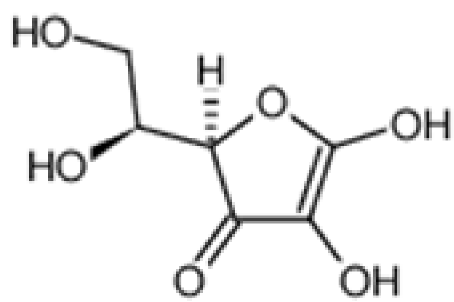
Sample #	Metal	thickness	mm		Porosity, %				
	Al	C	Ti	Finished sample	Al	C	Ti	sample	Weight, g/m^2
The density of free solid metal, g/cm^3	2.650	2.25	4.500						
1	0.1	0.5	0.1	Not pressed	46	4	52	49.2	5.25
2	0.2	0.5	0.1	Not pressed	46	4	52	49.2	7.75
3	0.1	0.5	0.1	50 KPa	21	4	23.5	24	7.25
4	0.2	0.5	0.2	50 KPa	21	4	23.5	24	22.15
5	0.3	0.5	0.2	50 KPa	21	4	23.58	22	26.35
6	0.5	0.5	0.5	50 KPa	20	4	21	18.5	39.5
7	1.0	0.5	0.5	100 KPa	12	4	13	12.5	57.2
8/	2	1.0	1.0	100 KPa	9	4	11	10	114
9	2	1.0	2.0	150 kPa	4	4	5	5	182
10	2	2.0	2.0	150 kPa	4	3	4	4	208

Discussion

This aim of the present study is to prepare a composite aluminium-graphite-titanium triple-layered metal sheet that would be regarded as a composite anisotropic and inhomogeneous material. Data of the periodic table shows that aluminium has an atomic weight of 26.9, and an atomic radius of 143.1 nm. It is one of the most ductile and malleable metals. Aluminium is non-magnetic. The metals of aluminium and titanium deposited in fine particles or crystals on the surface of the flake graphite-polymer sheet using the electroless process as shown in Fig.4. Alternatively, the triple sheet are prepared by hot pressing the three materials using a suitable adhesive binder. The particles of aluminium are spherical in shape (Fig, 7), whereas titanium particles are decahedral crystals with larger size (≈ 240 – 700 nm) as shown in Fig. 8.

Geometrically, the spherical particles have low contact surface area as compared to the decahedral ones with square top view. Under the experimental conditions of this work, the prepared samples were hot-pressed under 100 kPa. Pressing would cause a shape deformation of the spherically shaped particles. Richard Collins and others [15-18]. showed that materials for making aircraft are highly recommended to be lighter. In this context, this work is a starting step to develop metals composite for possible use in an aerospace application. The designed end products of A-C-Ti triple sheet include aluminium that is the classic metal in this industry and titanium which has a good thermal resistance and is a stiff material together with the graphite-polymer composite sheet. The latter is a distinguished material with good resistance to corrosion and thermal chock.

The method of preparation of the triple-layered metal sheet involved two alternative ways. The first method involves the chemical reduction of the metal ions in a solution using ascorbic acid. Ascorbic acid has the following structure



whereby (….H) is the active reducing atom

The reaction with aluminium or titanium nitrate or hydroxide Ti(OH)2 to give nanoparticles of free metal would take place according to

$Al(NO_3)_3 + 3C_6H_8O$ Al $+ 3C_6H_6O + 3$ NO $+ 3H_2O$…………….(1)

$2Ti(OH)_3 + 3C_6H_8O$ 2Ti $+3C_6H_6O + 6$ H_2O ………………….(2)

Similarly, the reaction assigned to reducing Al(OH)3 would proceed in a close way. It follows that regimenting metal particles would be pressed for cementing. The rate of particle formation and its followability to the graphite sheet would help to improve the mechanical strength of the prepared triple-layered metal sheet after rolling and sintering in particular. The mechanism of shaping the triple-layered sheet would take place similar to the technology of shaping metal powders. The force of rolling would be uniformly distributed to the particles. A major part of the rolling forces is retained at the intra-particle surface at certain active sites. Also, hot rolling of the metal particles with the graphite composite helps good binding the two metals; aluminium and titanium to the graphite composite plate. Carbon-reinforced fiber plastic and glass-fiber-reinforced aluminium composites with carbon nanotubes are types of composite materials typical to metal-matrix and ceramic-matrix composites that have a broad range in engineering applications.

The effect of rolling force on the apparent density value of the triple-layered Al-C-Titanium can be understood on the dislocation phenomenon of the metal powders with subsequent alignment to form solid metal with less porosity. Rolling aluminium powder with smaller size generally requires lower force while rolling of more hard titanium powder requires relatively higher force. Powder characteristics determine the extent of the rolling force. Additives also have a role in determining the desired density. The friction force between metal particles resists movement of particles during rolling, therefore lubrication can reduce the required rolling force and also cause a more uniform distribution of particles during rolling. Hot rolling decreases spaces, bridges and gaps in the solid metal and density increases due to a more efficient packing of the particles. Density measurement given in Fig. 6 shows that the density of the prepared triple-layered Al-C-Ti sheet decreases in the order standard, hot pressed (and annealed) and the sample prepared by chemical reduction without rolling. The findings are in agreement with the model given above.

Table 4 shows the characters of the finished triple-layered Al-C-Ti sheets. It is seen that the sample before rolling has a very high porosity extent based on it is just loose particles. The porosity decreases from ≈ 50 % to 4 % with increasing the rolling force up to 150 k Pa. Thermal properties of the prepared Al-C-Ti samples is reasonable. Measurements revealed that its thermal conductivity amounts to 46 W./m. °C as compared to 135 W./m. °C with aluminium, 1180 W./m. °C with pitch-bounded graphite (for ab direction) and 15.6 \W./m. °C with titanium metal. Such figures recommend the prepared triple-layered Al-C-Ti for possible application in the aeronautics industry.

Conclusion

Results show that triple-layered Al-C-Ti sheet prepared from aluminium, flake natural graphite polymer and titanium has been made by two alternative methods. The effect of the experimental parameters that determine the characteristics of the end products was studied. The triple composite samples were chosen to collectively benefit the outstanding thermomechanical properties of each metal in these composites. The sample prepared by chemical reduction of the nitrate ions using ascorbic acid was little week as compared to the hot-rolled cemented metals sheets with graphite plate. Hot rolling and annealing of the green samples werefound highly recommended to yield a triple-layered Al-C-Ti sheet with outstanding physical and thermal properties.

The ions of aluminum and titanium were reduced and deposited in microparticle size on the surface of the graphite-polymer sheet. The weight of the deposit is a time-dependent process, the rate-determining step is the diffusion rate of the ions towards the graphite surface. The weights / m2 of the finished triple-layered Al-C-Ti sheets are shown in table 4. A triple sheet having variant thickness was prepared after ≥ 250 min of diffusion. Temperature help enhancing the rate of diffusion but deteriorates the physic-mechanical properties of the prepared sheet. Thermal properties of the prepared Al-C-Ti samples is reasonable. Measurements revealed that its thermal conductivity amounts to 46 W./m.°C as compared to 135 W./m.°C with aluminium, 1180 W./m.°C with pitch-bounded graphite (for ab direction) and 15.6 W./m.°C with titanium metal. Such figures recommend the prepared triple-layered Al-C-Ti for possible application in the aeronautics industry.

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