



## Effect of Hot Rolling on the Intrinsic Properties of Aluminium-Titanium Bonded by PTFE/ C -Cyanoacrylate

Mahmoud A. Rabah <sup>1,\*</sup>



<sup>1</sup> Chemical and electrochemical treatments lab., Mineral Processing Dept, Central Metallurgical research and development Institute (CMRDI), 11421 El-Tebbin, Helwan, Cairo , Egypt

\*Corresponding author email: [mrabah010@gmail.com](mailto:mrabah010@gmail.com); [mahmoudrabah2@hotmail.com](mailto:mahmoudrabah2@hotmail.com)

DOI: <https://doi.org/10.34256/irjmt2133>

Received: 23-03-2021, Accepted: 06-04-2021, Published: 10-04-2021

**Abstract:** The concern of this study shows the effect of hot rolling on the properties of a composite sheet prepared from aluminium bonded to titanium metals sandwiching PTFE (Du Pont)/graphite emulsion in perfluoro kerosene. The metals were soaked in hot oxygenated water and dried at 80 °C for 5 - 10 minutes to create a thin film of oxide. The metals were bonded with cyanoacrylate blended to the polymer emulsion that applied to the oxidized surface of the clean metals. Two coated surfaces sandwich the polytetrafluoroethylene (PTFE)/graphite emulsion followed by hot-rolling. The rolling process was matched at 500- 560 °C ( $\approx$  150 °C, over the melting point of the PTFE) under a pressure of 150-200 KPa. The obtained composite sheet was annealed at 550 °C to remove any residual stresses. Results revealed that upon cooling, the mix microphase would separate with the OH radicals on the metal surface and the CF displaced away. The temperature and time of cyanoacrylate application enhanced the extent of adhesion to create a homogeneous composite metal sheet. The effect of the hot rolling conditions was ascribed to the PTFE underactivity and incompatibility. Rolling imparts squeezing of the metals and changes the intrinsic properties. Linear thermal expansion coefficient of the composite sheet confirms partial diffusion of the soft metal in the harder one across the adhesive. The applied technique deforms the PTFE particles without inhibiting the adhesion strength of the cyanoacrylate. The prepared sheet has physical properties that would be suitable for bailiwick and structural application.

**Keywords:** Al-Ti PTFE bonded laminar sheet, aeronautic sheet, PTFE as adhesive material

### 1. Introduction

The region materials to be used is also a gift in nature and won't to producing the first aircraft. Aerospace materials square measure developed metal alloys used for region applications or have returned to distinguished [1]. Materials engineering is rigid and a vital norm among the region application has been total. The international customary bodies maintain specifications for the materials and processes involved [2]. Engineers and academicians had performed intensive work for aeronautical materials improvement. The region materials to be used is also a gift in nature and won't to producing the early craft. Such materials were conjointly used once timber in wing structures and material and dope to cover them. the fabric quality was of utmost importance so the timber would be of fastidiously customary specifications was this extremely needed for the right choice, manufacture, and use of these materials. Specifications were then developed and updated with the cooperation of manufacturer's engineers or even government technicians and

sometimes with the help of university engineering departments.

Development of materials to be used within the region application was to adopt materials like means that, hardening of aluminium alloy(s) and evaluation of this goal. Several of those new materials and how to process the most effective use of them are reportable. The monetary and technical facilities and/or supervision of national laboratories and analysis establishments counselled aluminum or aluminum alloys for airframes, skin, and composites for structures. Some reporters expected that composite materials of aluminium metal could represent the roost once it involves region innovation and similar updated structures [3]. Altogether, patriarch et al [4] reportable the mechanical properties and fracture of Al-15 pastry primarily based metal matrix composites. it had been comparatively low value, particularly in comparison to aluminium or composites of aluminium alloys. The aluminum producer Co, Alcoa, in 2013, for instance, expected that around 6 June 1944 additional aluminum can be

employed in planes compared to 2011. the corporate, conjointly claimed that the present fleet of airliners and military jets square measure the most users of aluminum, and newer styles still specify countless this metal. It was reportable that one in every of the biggest traveler airliners within the world, contains ten times the number used as compared to the less updated model of the plane. Also, Boeing's 787 Dreamliner, is structured containing two-hundredth aluminum alloy 7085 (by weight), that was comparatively new [5].

Aluminium is alloyed with some nonferrous components like Mn, silicon, aluminium, magnesium, or metallic element and metallic element to any increase its strength. Cold operating could be a technique won't to increase the strength of those alloys. However, some alloys square measure any strong and hardened by heat treatment. Aluminium matrix composites: (MMCs) encompass metal alloys bolstered with fibers, whiskers, particulates, or wires. Alloys used as matrices thus far a square measure of aluminium-boron and Al-Mg. for instance, and in keeping with NASA space vehicle, 240 struts were fabricated from aluminium bolstered with B fiber. The investigator reportable the influence of some alloying components on the microstructures and mechanical properties of aluminium alloys and aluminium alloy composites [6]. once oxidized, aluminium forms a hard, microscopic compound protecting coating from the atmosphere. Al-Zn alloy 7075 is robust .as compared to steel. The alloy includes five.6-6.1% zinc, 2.1-2.5% atomic number 12, and 1.2-1.6% aluminum. it's in heat temper grade [7, 8]. With the correct choice and placement of carbon fibers, the composites of aluminium will be stronger and stiffer than steel elements with similar thicknesses of forty to seventieth. The chemical resistance is far higher than that of glass-reinforced composites. significantly alkalescent medium. However, carbon composites square measure comparatively brittle. they need no yield behaviour and their resistance to impact is low [9]. Thermal characteristics of carbon fibers disagree as compared to the alternative. This property helps in creating the planning of structures with zero or low linear and coplanar enlargement [10]. There square measure many varieties of aluminium adhesives with numerous cure mechanisms. Single part epoxy aluminium adhesives cure with heat to make high strength bonding. Permabond offers many grades which square measure colour matched to aluminium to look like fastening or brazing.[11].

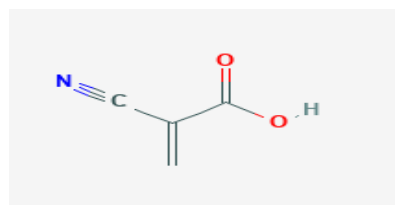
Amigo et, al reportable atomic number 22 and aluminium composites materials were bolstered by Ti-Al compounds [12]. The authors are reportable that numerous authors have studied microstructure/mechanical property relationships for discontinuously bolstered aluminium. The results of the reinforcements on the mechanical properties of the aluminium alloys square measure generally helpful whereas atomic number 22 and its alloys stand out

primarily to their specific strength and glorious corrosion resistance. Rajakumar [13] showed that the most important issue once the change of integrity commercially pure atomic number 22 (Ti) and aluminium (Al) lies in the existence of the formation of compound films and brittle intermetallic within the bond region. The diffusion bonding (DB) method parameters like bonding temperature, bonding pressure, and holding time play a major role to see the joint strength.

Cao et. al [14] studied the influences of interface morphology, diffusion layer and reaction product, constraint effect on the mechanical properties of the laminar metals composites (LMCs). The detailed conclusions were reported as follows:

1. The increase of hot-pressing temperature changes the morphologies of Ti/Al interface to the waveform, and the intermetallic phases don't change. The width of the intermetallic phases layer at Mg/Al interface increases significantly with the increasing temperature.
2. The increase of hot-pressing temperature, both bonding strength and hardness of Ti/Al interface increase and the maximum bonding strength is obtained at 400 °C.
3. The increase of temperature, UTS of LMCs increases at the expense of FE propagation.

Zhang et al., [15] reported that with increasing temperature, the thickness in layer diffusion increased and the mechanical properties of LMCs improved.



$C=C(C\#N)C(=O)O$  anoacrylic

This paper has its aim to check the impact of pH on the steadiness of bonded aluminium-titanium metals sandwiched with PTFE/graphite replacing the insert moulding technique. The composite metal sheet of Al blended in perfluoro kerosene and adhered by cyanoacrylate adhesive. The impact of the roll bonding temperature on the intrinsic properties of Al -titanium sandwiching PTFE/graphite using cyanoacrylate adhesive was studied.

## 2. Experimental

### 2.1 Materials and Method

The polymer tetrafluoroethylene was the product of Du point, Danisco Egypt Trading Co., New Cairo.

The perfluoro kerosene adhesive (2-Methyl-2-butene) was supplied by Merck. A polymer PTFE sample weighing 10 g was dissolved in 100 ml perfluoro kerosene-L having the chemical formula  $C_5H_{10}$ , and doped with synthetic aluminum hydroxide (5wt %). A similar quantity of flake graphite fine powder (<10  $\mu m$ ) was added to form an emulsion for the power spraying on the clean surface of aluminium and titanium sheets.

The following Table 1 gives the characteristics of the PTFE and perfluoro-kerosene.

Synthetic  $Al(OH)_3$  was prepared by dissolving Al metal in 3 M HCl and filtered. The obtained  $AlCl_3$  was treated with ammonia to give gelatinous  $Al(OH)_3$  at a pH value of 8.

Properties of the used graphite

- It has a high melting point, similar to that of diamond.
- has a soft, slippery feel, and is used in pencils and as a dry lubricant for things like locks. ...
- has a low density (2.15 - 2.20  $kg/d.cm^3$ )
- is insoluble in water and organic solvents.

Table 2 shows the thermal properties of the used graphite

### 2.2 The chemicals used

- Table 3 shows the properties of the chemicals used.

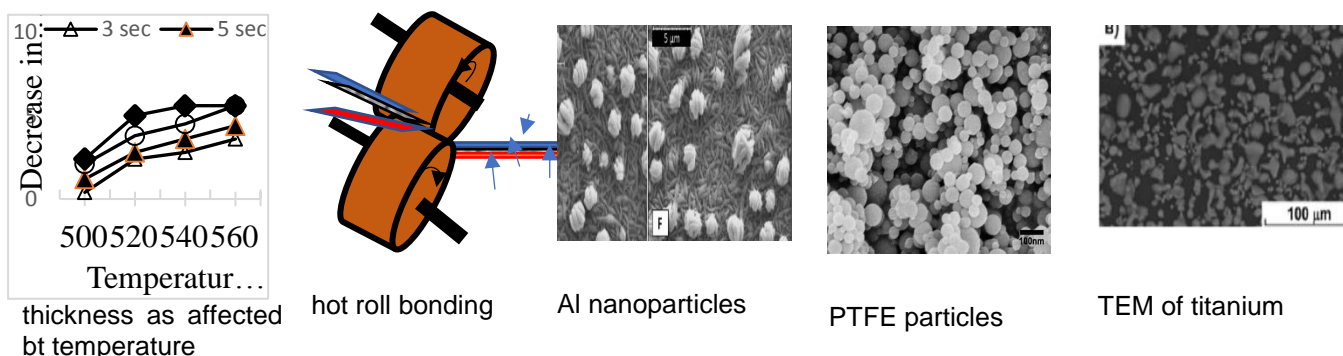


Figure 1. The graphical abstract

Table 1 The characteristics of the PTFE and perfluoro-kerosene

Property	ASTM method	init	PTFE Granular Resin
Tensile strength, 23°C	D4894/4895	MPa )psi)	31
Elongation, 23 °C	D4894/4895	%	400
Hardness durometer	D 2240	Shore D	55
Volume resistivity	D 257	Ohm's	➤ $10^{18}$
Surface resistivity	D 257	Ohm's	➤ $10^{18}$
Perfluoro-kerosene			
Boiling point	°C	70 - 240	
Density	g/mL at 25 °C	1.94	
Refractive index	$n_{20/D}$	Lit.	
Flash point	°F	115	
Linear thermal expansion coefficient		( $10^{-6} m/(m °C)$ )	7. 4 ~ 27

**Table 2** The thermal properties of the used graphite

properties		T68	Unit	Tole Tolerance r	Test Method
Thermal Conductivity	XY axis	1500	W / mK	±100	AC calorimeter
	Z axis	5	W / mK	±0.5	Laser flash
Color		Black	–	–	Visual
Thermal Diffusivity		8.5	cm <sup>2</sup> / S	±0.5	AC calorimeter
Density		2.1	g / cm <sup>3</sup>	±0.1	Archimedes law
Electrical Conductivity		>13000	S / cm	–	JIS K7194
Flexural Strength		10000	times	–	-
Working Temperature		-40~400	°C	–	AC calorimeter
Heat Capacity (HC)		0.895	J / g-K	–	–
Linear thermal expansion coefficient		4-8	(c)		

**Table 3** Properties of the chemicals

chemical	Source	Purpose	Property
Nitric acid	SP.GR.1.18 (AR)	Leaching	ADWIC
	Min. assay 36 %	Process	Riedel- de Hein
	Fuming 69 %		ADWIC
H <sub>2</sub> SO <sub>4</sub>	H <sub>2</sub> SO <sub>4</sub> 95-97%		
	Extra pure		
HCl	SP.GR.1.18 (AR)		
Ca CO <sub>3</sub>	Green Egypt	Synthesis process	99.3,
EJSF2	Sigma Aldrich		1.6 um
Ca oxide			3.34 g/cm <sup>3</sup> , 1.57 um
NaOH	United Co.		reagent for analysis
Ammonium hydroxide	for chemicals & Med. Preparations		25 % Pure reagent for analysis
AgNO <sub>3</sub> (Silver Nitrate)		Chloride ion determination	Pure reagent for analysis
distilled water		Chemical reactions	
Tap water		Other purposes	

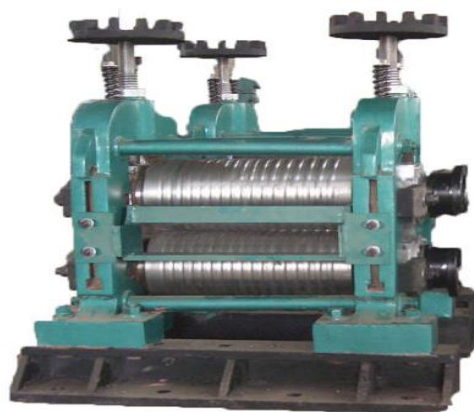
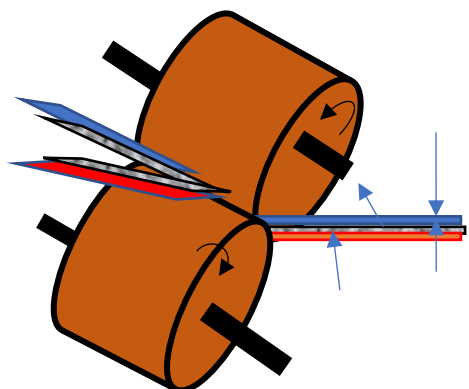


Figure 2a Assembly of the Bonding device

Figure 2b Photograph of the double roller machine

Table 4 Summary of the composition of the prepared samples

Sample #	Thickness, $\mu\text{m}$				Hypothetical total thickness, $\mu\text{m}$	Al: Ti mass ratio	Bonding,	
	Al	Ti	PTFE	adhesive			T, $^{\circ}\text{C}$	t, sec.
1	100	50	100	1	251	1.16	500	3
2	100	75	100	1	276	0.77	550	5
3	100	100	100	1	301	0.58	600	8
4	200	100	50	1	351	1.16	500	3
5	200	100	100	1	401	1.16	600	5
6	200	200	100	1	501	0.58	500	8
7	300	200	100	1	601	1.74	600	5
8	250	200	150	2	602	1.45	500	8
9	250	250	150	2	652	0.77	550	5
10	250	250	200	2	702	0.77	600	8

Table 5 The percent decrease in thickness of the triple sheet upon bonding Al: Ti and PTFE/C

	$\Sigma 5 - 20$ sec.	$\Sigma 20 - 40$ Sec.	$\Sigma 40 - 60$ sec.	$\Sigma 5 - 20$ sec.	$\Sigma 20 - 40$ sec.	$\Sigma 40 - 60$ sec.	$\Sigma 0 - 20$ sec.	$\Sigma 0 - 40$ sec.	$\Sigma 0 - 60$ sec.
1	0.8	0.45	0.3	0.76	0.66	0.50	1.56	1.91	2.41
2	0.68	0.41	0.28	0.60	0.36	0.30	1.104	0.77	2.085
3	0.51	0.28	0.24	0.80	0.28	0.211	1.310	0.56	2.081
4	0.80	0.448	0.388	0.60	0.65	0.211	1.310	0.56	2.842
5	0.83	0.482	0.396	0.75	0.58	0.303	1.58	1.082	2.965
6	0.85	0.490	0.405	0.37	0.38	0.188	1.22	0.870	2.278
7	0.86	0.492	0.416	0.424	0.454	0.222	1.264	0.870	2.356
8	0.76	0.475	0.400	0.360	0.620	0.260	1.120	1.095	2.475
9	0.54	0.408	0.346	0.214	0.310	0.170	0.754	0.718	1.642
10	0.54	0.412	0.352	0.196	0.298	0.736	0.736	0.710	1.626

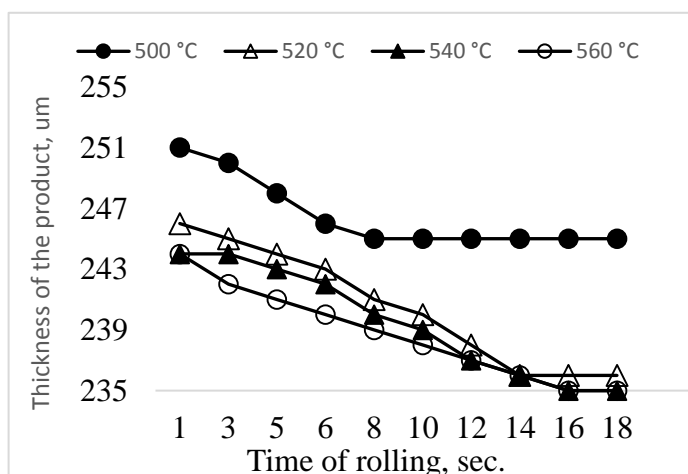


Figure 3. Effect of time of rolling on the thickness of the triple layered sheet # 1 at temperatures up to 560 °C.

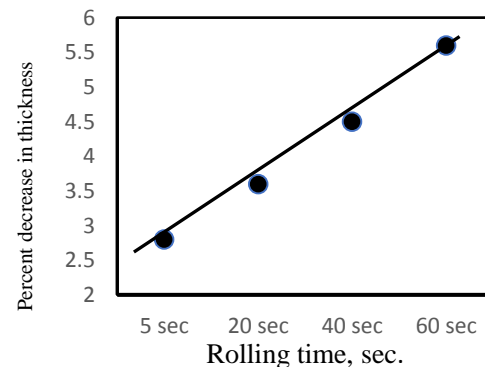
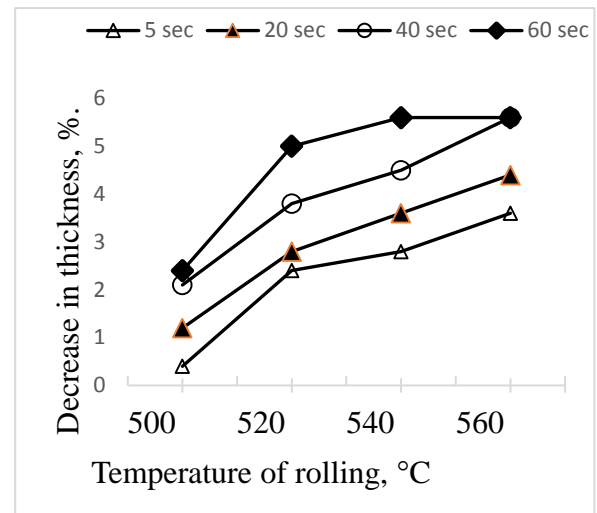
### 3. Results

Fig. 1 shows the graphical abstract of this manuscript. It contains the SEM image of the aluminium metal and the PTFE. A schematic diagram of the double roller for the preparation of the triple layered sheet by mechanical bonding method. The graphical abstract also contains a figure of the effect of temperature on the TLMC thickness. Fig. 2a,b shows an assembly of the rolling device (2a) and a photograph of the double roller (Fig. 2b).

Figure. 3 shows the effect of the rolling time on the thickness of sample #1 at temperatures up to 560 °C. It is seen that at 500 °C, the increase in bonding time up to 40 seconds causes a corresponding decrease in the thickness after which more increase in time of bonding becomes immaterial. For one and the same bonding time, increasing the bonding temperature causes a further decrease in the thickness of the prepared samples.

Fig. 4a shows that a linear relation holds the rolling time and the percent decrease in the thickness of the prepared TLMC samples. Fig. 4b checks the effect of temperature on the thickness of sample #1 upon hot rolling. It is seen that the increase in the rolling temperature causes a decrease in the thickness. The effect becomes more significant with increase in rolling time up to 60 sec.

Fig. 5a shows the effect of Al : Ti mass ratio on the magnitude of thickness of the rolled triple sheet at 550 °C for 40 sec. It is seen that the thickness decreases regularly from 0.65  $\mu\text{m}$  with 1.74 Al : Ti to 0.38  $\mu\text{m}$  with 0.58 Al : Ti mass ratio. Fig. 5b shows the effect of sample composition on the thickness magnitude of the bonded samples as a function of rolling time at 5-20 sec., 20 – 40 sec. and 50-60 sec. It is seen that the thickness of the sample decreases with the increase in the titanium metal and decreases with higher rolling time.



**Fig 4a** Effect of rolling time on percent decrease in thickness of the Al : Ti mass ratio of the prepared TLMC samples.

**Fig. 4b** Effect of rolling temperature on the percent decrease in thickness (sample #1.)

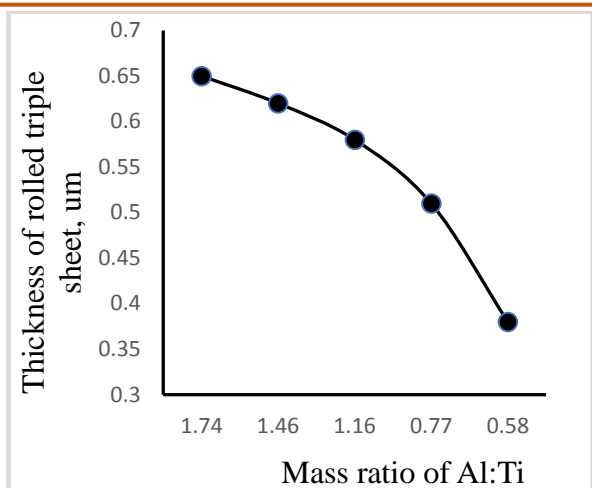


Fig. 5a Effect of Al:Ti mass ratio on the thickness of the roll bonded triple sheet at 550 °C for 40 sec.

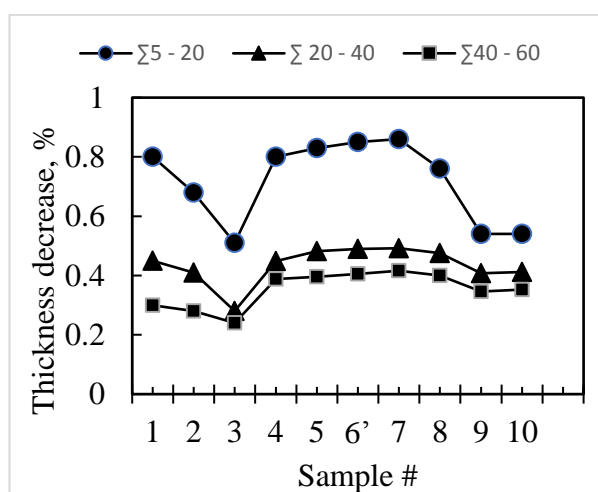


Fig. 5b Effect of sample composition on the decrease in thickness of samples bonded at 550°C for 40 sec

Fig. 6a shows the density of the triple-layered sheet prepared with different thickness of titanium and constant thickness of aluminium at 0.2 mm. It is seen that the density value increases slightly with the increase in the thickness of the titanium layer. Density attains a value of 2.53 g/cm<sup>3</sup> with samples having about 0.38 mm titanium in thickness. Fig. 6b 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 is seen that the density value displays the same trend as shown in Fig. 6a provided that the value of the density is comparatively higher.

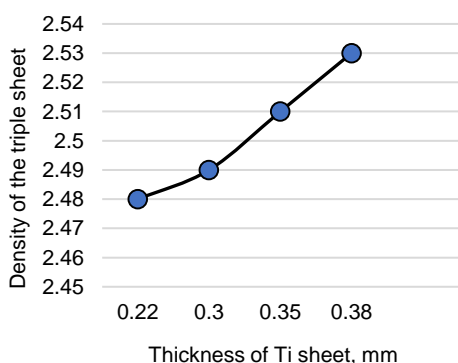


Figure 6a The density of the triple-layered sheet having different thickness of aluminium and a constant thickness of titanium of 0.2 mm

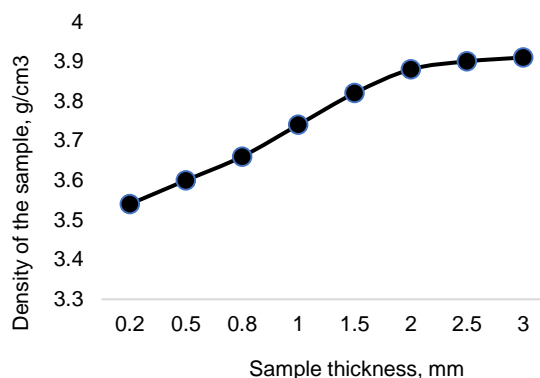


Figure 6b Thickness of the prepared triple-layered Al-PTFE/C-Ti samples

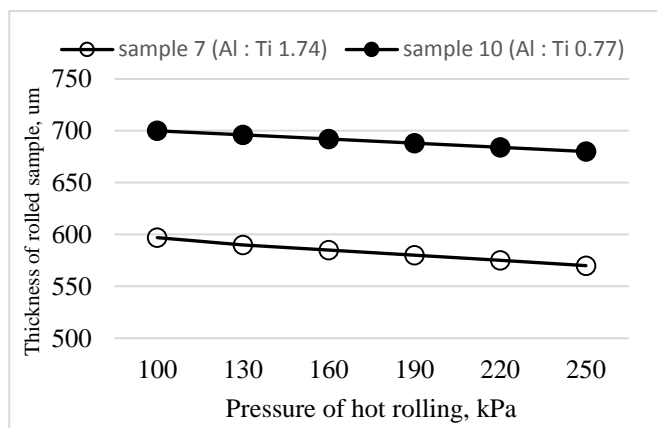


Figure 7 Effect of hot rolling pressure on the thickness of the rolled sample at 500°C.

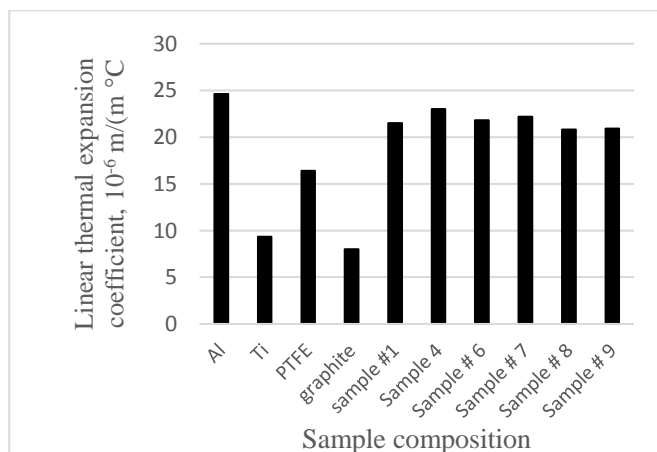


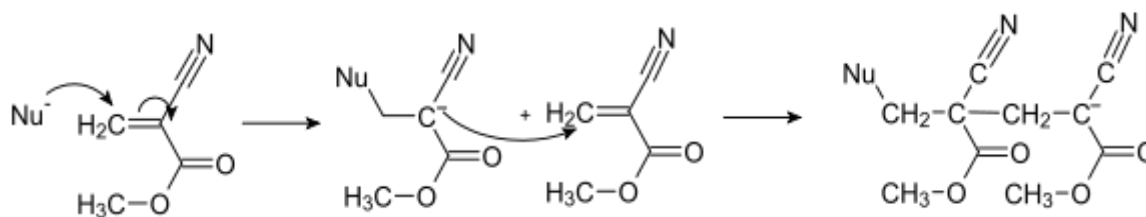
Fig 8 The linear thermal expansion coefficient (LTEC) of the prepared samples

Fig 7 shows the effect of pressure of rolling at 500 °C on the rolled triple layered sheet with samples # 7 and 10. It is seen that increasing the pressure of hot rolling linearly decreases the thickness of the sample.

Fig 8 shows the linear thermal expansion coefficient (LTEC) of the prepared samples. It is seen that the LTEC value increases in the order Al metal, samples having high Al content, titanium and graphite.

**Table 6** Technical details of the finished triple-layered Al-C-Ti sheets

Sample #	Thickness, um				Space separating layers nm				Density, g/m <sup>2</sup>	
	Al	PTFE/C	Ti	Finished sample	Al /	C /	Ti	S sample		
The density, g/cm <sup>3</sup>	2.650	2.25	4.50	Hypo-thetical	measured					
1	100	10	50	160	155	4.6	4	52	49.2	5.25
2	200	50	100	350 340		4.6	4	52	49.2	7.75
3	100	50	100	250 242		3.2	4	23.5	24	7.25
4	200	50	200	450 440		3.2	4	23.5	24	22.15
5	300	50	200	550 540		3.2	4	23.58	22	26.35
6	500	50	500	1050 1035		3.0	4	21	18.5	39.5
7	1 mm	50	500	1550 1442		3.0	4	13	12.5	57.2
8/	2 mm	1 mm	1 mm	4 mm 3.86 mm		3.0	4	11	10	114
9	2 mm	1 mm	2 mm	5 mm 4.85 mm		2.9	4	5	5	182
10	3 mm	1 mm	3 mm	7 mm 6.80 mm		2.9		4 4	3	208



Synthesis Polymerization of methyl 2-cyanoacrylate

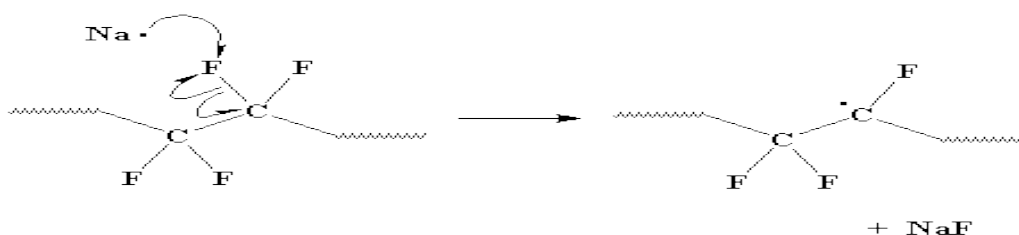


Table 6 shows the technical details of the finished samples of triple-layered Al-C-Ti sheets prepared by hot roll bonding technique.

The cyanoacrylate adhesive is commercially known as super glue. The material is used to combine anything from metal to plastic and even human skin and frequently used in bonding the following:

**4. Discussion**

1. Aerospace components



2. Automotive subassemblies
3. Musical instruments
4. Appliance part assembly
5. Disposable medical device applications.

PTFE, it is an important material in the industry because of the following reasons.

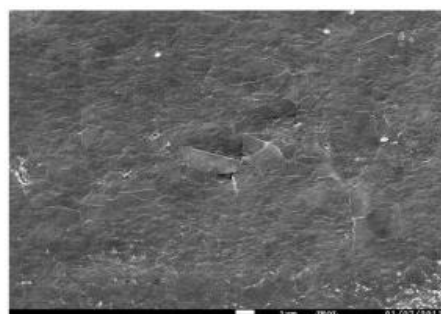
- a. It is a tough, flexible, non-resilient material.
- b. is used in aircraft where high temperature resistance is required.
- c. Has an average tensile strength.
- d. Great thermal properties.
- e. Excellent resistance to chemicals and passage of electric current.
- f. PTFE is an outstanding insulator over a wide range of temperatures and frequency.
- g. It is outstanding and chemically stable.
- h. PTFE is insoluble in the organic solvents.
- i. The PTFE polymer is a thermoplastic material. However and due to its high viscosity, it cannot be processed using conventional polymer processing techniques. Hence, PTFE is processed by cold shaping operation followed by heat treatment (sintering) during which the polymer particles fuse to form a solid molding.

Aluminium metal doesn't rust because a thin layer of a protective aluminium oxide forms on the surface of the metal. Upon cooling of the hot homogenized polymer poured on aluminium surface, the mix would microphase separate with the OH moiety concentrating on the metal surface and the carbon fluoride CF migrating away from it. The H-bonds are stronger than Van Der Waals interactions and the two metals are chemically bonded. The entropy of the bond case would be such that chains of CF remain imbedded in chains of OH. It would be hard enough to get small molecules to crystallize quantitatively. Once the mixture set-up on the metal surface, heating would not return the coating to homogeneity.

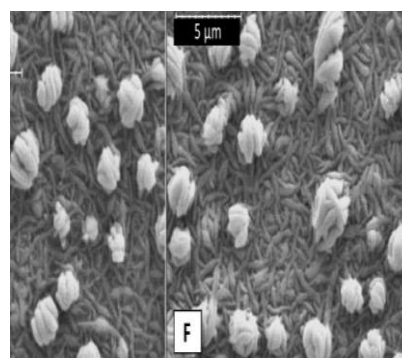
The experimental protocol includes washing of the two metals (Aluminium and titanium) with oxygenated hot water. The aluminum and titanium would corrode and their own corrosion products would aid in binding to PTFE. A copolymer would probably work better than the blend that would indeed tend to phase separate. The polymer don't gain very much entropy on blending, so they don't blend unless there are strong enthalpic interactions. So PTFE would probably phase separate. Rough surfaces helps

adhesive to stick to a surface because of the increase the working area of the two surfaces in contact. The interactive forces of PTFE are repulsive imparting roughening the surface will only increase the force of the repulsion between the two metal surfaces.

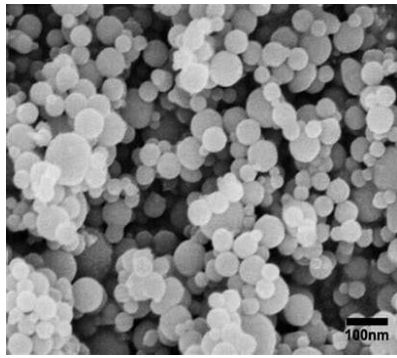
This aim of the present study is to prepare a composite aluminium-titanium-PTFE/C triple-layered metal sheet that would be regarded as a composite anisotropic and inhomogeneous material. Data of the periodic table shows that aluminium has an atomic weight of 26.9, and an atomic radius of 143.1 nm. It is one of the most ductile and malleable metal. Aluminium is non-magnetic. The metals of aluminium and titanium are structured in fine particles or crystals as seen in Fig. 8. Fig. 8a show SEM images of the graphite-doped polymer emulsion (in perfluoro kerosene). Fig. 8b is the SEM of Al particles while Fig.8c shows the SEM image of PTFE particles and Fig. 8d is the TEM of titanium .



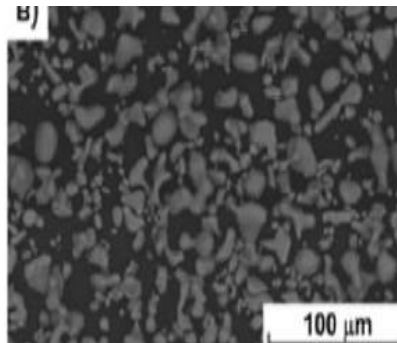
**Fig 8a** SEM images of the graphite-doped polymer emulsion in perfluoro kerosene.



**Fig. 8b** SEM image of Al particles



**Figure 8c** image of PTFE



**Figure 8d** TEM of titanium

Titanium particles are small-sized crystals (24 – 700 nm) with larger extent as shown in Fig. 8d. Under the experimental conditions of this work, the prepared samples were hot roll bonded. The composite sheet is hot-rolled under 150-200 kPa. Pressing would cause a shape deformation of the spherically-shaped particles. Richard Collins [16] et al., for creating aircraft are highly recommended to be lighter. during this context, this work light aluminium, PTFE/graphite and titanium are used as a step to develop metals composite for possible use in an engineering application. The products of Al-PTFE/C-Ti triple sheet include aluminium because the classic metal and titanium which has good thermal resistance properties and could be a stiff material along with the PTFE polymer composite sheet. The latter could be a distinguished material with good resistance to corrosion and thermal shock.

The mechanism of shaping the triple-layered sheet would occur in a very similar thanks to the technology of shaping metal powders. The force of roll bonding would be uniformly distributed to the particles. a serious part of the roll bonding forces is retained at the intra-particle surface at certain active sites. Also, hot roll bonding of the 2 metal particles with the PTFE/graphite composite helps good binding the 2 metals using cyanoacrylate. Aluminium and titanium form a composite plate. The effect of roll bonding force on the apparent density value of the triple-layered Al-PTFE/C-titanium may be understood on the

premise that the process involves the dislocation of the metal crystals with subsequent alignment to make solid metal with less porosity. Roll bonding aluminium to create smaller leaflet-shaped particles requires lower force while roll bonding of more hard titanium powder requires relatively higher force. Additives even have a job in determining the specified density. The friction force acting between metal particles resists movement of particles during rolling, therefore lubrication can reduce the specified roll bonding force and cause a more uniform distribution of particles during the method. Hot roll bonding decreases the spaces and gaps within the solid metal and density increases due to packing of the particles.

Density measurement given in Fig. 6 shows that the density of the prepared triple-layered Al-PTFE/C-Ti sheet. The findings believe the model given above. Table 6 shows the properties of the finished triple-layered Al-PTFE/C-Ti sheets. it's seen that the sample before roll bonding features a very high porosity extent based on that is simply loose particles. The porosity decreases from  $\approx 50$  you must 4 you bored with winding up the roll bonding force up to 150 k Pa. In Fig. 7 results show that the pressure of hot rolling linearly decreases the thickness of the rolled samples given that the upper the Al: Ti ratio the lower the thickness becomes. In Fig. 8 the linear thermal coefficient property of the prepared Al-PTFE/C-Ti samples seems reasonable on basis of the collective thermal properties and therefore the weight ratio of the components forming the triple sheet. 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 would recommend the prepared triple-layered Al-PTFE/C-Ti for possible application within the engineering industry.

## 5. Conclusion

Results show that triple-layered Al-PTFE/C-Ti triple sheet prepared from aluminium, titanium and PTFE/graphite emulsion in perfluoro kerosene and using cyanoacrylate adhesive has been prepared. 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. Hot roll bonding and annealing of the samples were found highly recommended to yield a triple-layered Al-PTFE/graphite-Ti sheet with outstanding physical and thermal properties. The weights / m<sup>2</sup> of the finished triple-layered Al-PTFE/C -Ti sheets are shown in table

6. A triple sheet having variant physical and chemical properties was prepared after different time and pressure of hot rolling. Temperature help enhancing the metal reforming and bonding of the components. Thermal properties of the prepared Al-PTFE/C-Ti samples found reasonable. Measurements revealed that the thermal conductivity of the samples 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. The thermal linear expansion coefficient ranged from 20.9 10<sup>-6</sup> m/(m °C to 23 10<sup>-6</sup> m/(m °C. Such figures recommend the prepared triple-layered Al-PTFE/C-Ti for possible application in the engineering in general and aeronautics industry.

## References

- [1] S. Ajaya Kumar, A. Prabhu Kumar, B. Balu Naik, B. Ravi, A Review on the Mechanical Properties of Aluminum Based Metal Matrix Composites (MMCs), *International Journal of Engineering Science Invention*, 6 (2017) 12-15.
- [2] L.E.G. Cambroner, E. Sánchez. J.M. Ruiz-Roman, and J.M. Ruiz-Prieto, Mechanical characterization of AA7015 aluminium alloy reinforced with ceramics, *Journal of Materials Processing Technology*, 143-144 (2003) 378–383. [https://doi.org/10.1016/S0924-0136\(03\)00424-2](https://doi.org/10.1016/S0924-0136(03)00424-2)
- [3] Sano, T., Srivatsan, T.S. (Eds.), *Advanced Composites for Aerospace, Marine, and Land Applications II*, Verlag: Springer International Publishing, 2016. <https://doi.org/10.1007/978-3-319-48141-8>
- [4] M.F. Ibrahim, H.R. Ammar, M. Samuel M.S.A. Soliman and F.H. Samuel, Mechanical properties and fracture of Al Aluminum 6092/B4C (boron carbide), *Metals and Materials International*, (23) (2017) 813–822.
- [5] M.F. Ibrahim et al., Mechanical properties and fracture of Al–15 vol.-%B4C based metal matrix composites, *International Journal of Cast Metal Research*, 1 (2013) 7-14.
- [6] B.S. Murty and S. Ranganathan, Chapter-1, A Brief History of Alloys and the Birth of High-Entropy Alloys, *High Entropy Alloys 2014*, Pages 1-12. <https://doi.org/10.1016/B978-0-12-800251-3.00001-8>
- [7] Rana, Rajesh Purohit, and S. Das, Reviews on the alloying elements on the microstructure and mechanical properties of aluminium alloys and aluminium composites, *International Journal of Scientific and Research Publications*, 2 (2012) 1-7.
- [8] E. Magnello, *A Century of Measurement: History of the National Physical Laboratory* HMSO 2000, p. 16. ISBN 0-9537868-1-1.
- [9] R.A. Higgins, Part I: *Applied Physical Metallurgy, Engineering Metallurgy* (5th ed.). Hodder & Stoughton. 2017, pp. 435–438. ISBN 0-340-28524-9.
- [10] C. A. F Clinton and R.A.S. Arnold, *Machining Operations on the 'Bristol Mercury: Engine, Aero Engineering*. Volume II, part 1. George Newnes. 1938, pp. 378–383.
- [11] Permabond Engineering adhesives, Internet, 2020, PTFE adhesive - Industrial adhesives for bonding PTFE.
- [12] V. Amigó. F. Romero, C.E. Da Costa and M.D. Salvador, Titanium and aluminium composites materials reinforced by Ti-Al compounds, [https://www.ipen.br/biblioteca/cd/ptech/2005/PDF/07\\_07.PDF](https://www.ipen.br/biblioteca/cd/ptech/2005/PDF/07_07.PDF) .
- [13] S. Rajakumar, and V. Balasubramanian, Diffusion bonding of titanium and AA 7075 aluminum alloy dissimilar joints—process modeling and optimization using desirability approach, *The International Journal of Advanced Manufacturing Technology* 86, (2016) 1095–1112. <https://doi.org/10.1007/s00170-015-8223-7>
- [14] Miao Cao, Cui-ju Wanga un-kun Deng Kai-bo Ni Wei Liang and Yu-cheng Wu, Effect of Interface on Mechanical Properties of Ti/Al/Mg/Al/Ti Laminated Composites, *Materials Research*, 23 (2020). <https://doi.org/10.1590/1980-5373-mr-2019-0648>
- [15] Cheng Zhang, Shouxin Wang, Hanxue Qiao, Zejun Chen, Taiqian Mo, and Qing Liu Enhancing the Mechanical Properties of Hot Roll Bonded Al/Ti Laminated Metal Composites (LMCs) by Pre-Bonding Diffusion Process, *Metals* 9 (2019) 795. <https://doi.org/10.3390/met9070795>
- [16] R. Collins, Out of the lab and into a plane: The emerging materials making aircraft lighter, *Aircraft Interiors*, 2018, online Jul 24 – IDTechEx

## Funding

No funding was received for conducting this study.

**Conflict of interest**

The Author has no conflicts of interest to declare that they are relevant to the content of this article

**About the License**

© The author 2021. The text of this article is open access and licensed under a Creative Commons Attribution 4.0 International License

**Cite this Article**

Mahmoud A. Rabah, Effect of Hot Rolling on the Intrinsic Properties of Aluminium-Titanium Bonded by PTFE/ C - Cyanoacrylate, International Research Journal of Multidisciplinary Technovation, Vol 3, Iss 3 (2021) 12-22.

DOI: <https://doi.org/10.34256/irjmt2133>