Available online at www.ijapie.org

International Journal of Advanced Production and Industrial Engineering

IJAPIE-SI-MM 512 (2017) 81–84

Special Issue on

MATERIALS & MANUFACTURING

Synthesis and Wear Behaviour of $(Al, Cu)_3Ti$ Powder Blend by Mechanical Alloying

Shailesh Kumar Singh*[1], Satyajeet Kumar[1], Jay Shankar kumar[1], Sitikantha Behera[1], Shailesh Mani Pandey[2]

[1](*Department of mechanical Engineering, Krishna Engineering College, Ghaziabad 201007, India)*

[2](*Department of mechanical Engineering, Delhi Technological University, Delhi110042, India)*

**Email:* shaileshsonu10@gmail.com

Abstract : In the present investigation, an attempt has been made to study the formation of intermetallic compound for $Al_{70}Cu_{22}Ti_8$ alloy composition by mechanical alloying. Elemental powder of $Al_{70}Cu_{22}Ti_8$(all in wt. %) composition was milled in a Fritsch pulverisette planetary mill for 50h under toluene. Powder of 1wt. % Y_2O_3 and 1wt. % TiO_2 were added separately to the 50 h milled base alloy powder to study the effect of oxide dispersion. A maximum of 81% theoretical density was obtained for the composite powder mixture sintered at 1100^0C for 1h. A maximum Vickers microhardness of 449, 649, 872HV were obtained for base alloy, Y_2O_3 and TiO_2 dispersed alloy sintered at 1100^0C for 1h respectively. It was also found that TiO_2 and Y_2O_3 dispersed base alloy have higher wear resistance than base alloy.

Keywords: Synthesis and wear behaviour , $(Al_, Cu)_3Ti$ powder blend, mechanical alloying

INTRODUCTION

In earth crust aluminium is present in hydrated oxide form of which bauxite is the primary ore. The aluminium alloys are light weight ($2.77g/m^3$) and easy to manufacture. Aluminium alloys have high specific strength approximately 3 times that of structural steel. So, aluminium alloys are primary used for consumption and production after steel [1].But today's modern world calls for materials with a combination of properties that cannot be met by single metal like polymer, ceramic and metal alloys. This combination of material properties is achieved by the development of intermetallic [2].Intermetallic is new class of most advanced materials. Intermetallic has different crystal structure than that of the parent materials. The intermetallic compound formation occurs when the bond strength of similar atoms (Al-Al) is less than that of bond strength of unlike atoms (Al-Ti).Intermetallic have properties between metal and ceramics because they have order distribution of atom [3].

Intermetallics have high structural material because they have high oxidation resistance, low density and high melting point temperature etc. [4-9]. Intermetallic can replace the super alloy and stainless steel as they process high melting point [10]. Intermetallic widely applied for high temperature structural application so they generally used in jet engine to withstand the operating temperature and reduce the weight of the engine.At room temperature most of intermetallichas less toughness and the manufacturing cost of intermetallic compound is too high. Due to extrinsic factor the ductility of intermetallic is less but exception is FeAl intermetallic.Al_3Ti intermetallic has low density i.e. $3.31g/cm^3$ and high oxidation resistance [11]. At room temperature the Al_3Ti intermetallic shows 216 GPA of young's modulus which is more than other titanium aluminaides. Most super alloys have this range of young's modulus hence it can substitute super alloy. As Al_3Ti intermetallic is light weight it is used in aerospace application [12]. At low temperature Al_3Ti intermetallic is brittle but when exposed to air Al_2O_3 layer formation occurs as a result oxidation resistance increases [10, 11].

MATERIALS AND METHOD

Synthesis of $(Al,Cu)_3Ti$ powder blend

Synthesis of $(Al, Cu)_3Ti$ powder blend were performed by mechanical alloying followed by conventional pressure less sintering.

Table-1 Milling parameters used for planetary milling of $(Al ,Cu)_3Ti$

Milled parameter	Value
Rotation speed (rpm)	300
Ball-power weight ratio	5:1
Al: Cu: Ti (wt %)	70:22:8
Type of ball	steel
Milling time (h)	0 , 10 , 20 , 30 , 40 , 50
Grinding medium	toluene
Cointainer volume (ml)	250
Steel ball size (mm)	15 , 10

Elemental powder of the composition $Al_{70}Cu_{22}Ti_8$ (all in wt. %) were milled for 0, 10, 20, 30, 40 and 50 h in a Fritsch pulverisette planetary mill. To avoid oxidation of powders during milling toluene ($C_6H_5CH_3$) was used to fill to just pass over the balls and powders. The details of milling parameters are mentioned in Table 1.

Fifty hours milled base powders were mixed separately with 1 wt. % of Y_2O_3 and TiO_2 powders by pestle and mortar for 1 hour. Then the mixed powders were cold compacted by hydraulic press using a load of 450MPa. Pellets of 15mm diameters were prepared by cold compaction. The cold compacted pellets were then sintered in a tubular furnace at 900°C, 1000°C and 1100°C for different times under a flowing argon gas. The different sintering parameters used are represented in Table 2.

Table-2 Sintering parameters used for different pellets

Elemental power	Compaction pressure (MPa)	Sintering temp (°C)	Holding time (h)	atmosphere
$Al_{70}Cu_{22}Ti_8$	450	900	2	argon
	450	1000	1	argon
	450	1100	1	argon
$Al_{70}Cu_{22}Ti_8$ -TiO_2(1 wt. %)	450	900	2	argon
	450	1000	1	argon
	450	1100	1	argon
$Al_{70}Cu_{22}Ti_8$ -Y_2O_3 (1 wt. %)	450	900	2	argon
	450	1000	1	argon
	450	1100	1	argon

RESULTS AND DISCUSSIONS

Hardness measurement

Figure-1 shows the hardness of $Al_{70}Cu_{22}Ti_8$ (base alloy), Y_2O_3 and TiO_2 dispersed base alloy sintered at 900, 1000 and 1100°C respectively. It is shown from the graph that hardness of base alloy and Y_2O_3 and TiO_2 dispersed base alloys increases with temperature. However, the rate of increase of hardness of base alloy is less as compared to Y_2O_3 and TiO_2 dispersed base alloy. The hardness values of base alloy increases from 409 to 449 as sintering temperature increases from 900 to 1100°C. With the addition of 1 wt. % nanoY_2O_3 and TiO_2 hardness drastically increases. The hardness values of Y_2O_3 dispersed base alloy are 421, 442 and 649 at 900, 1000 and 1100°C respectively. Similarly, the hardness value of TiO_2 dispersed base alloy are 572, 593 and 872 at 900, 1000 and 1100°C respectively. From the hardness data it is clear that hardness is highest for TiO_2 dispersed alloy and lowest for base alloy. The hardness increases drastically with the addition of hard and brittle TiO_2 and Y_2O_3 particles. Another reason of high hardness after addition of TiO_2 and Y_2O_3 particles is due to the formation of hard and brittle Al_2O_3 phase as evident from XRD spectrum.

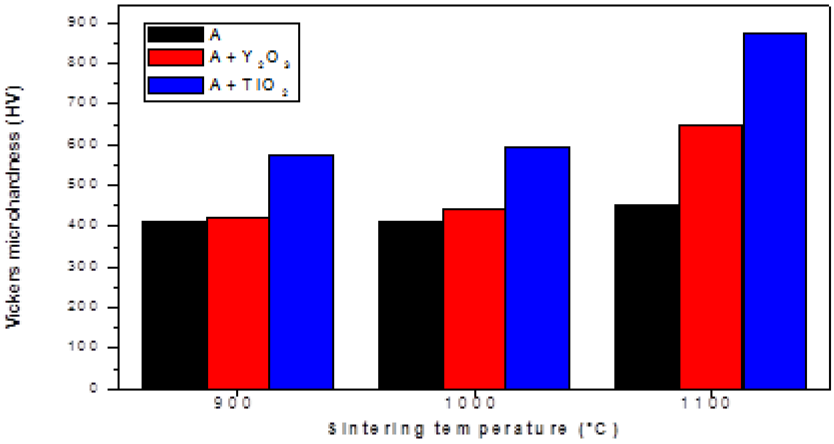
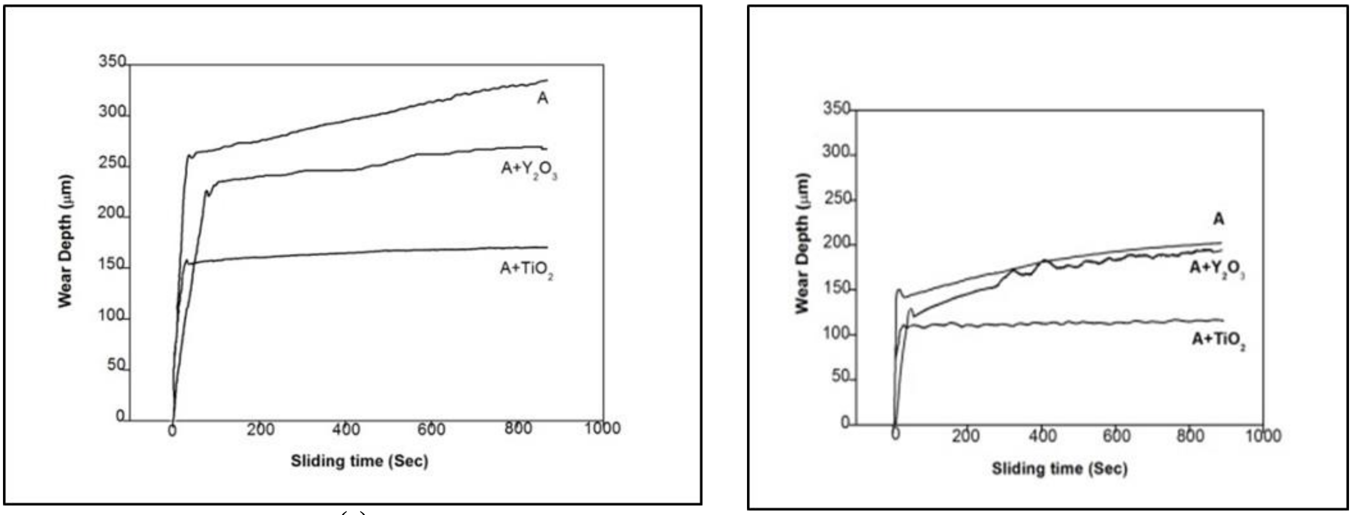


Figure-1 Bar chart of Vickers micro-hardness of $Al_{70}Cu_{22}Ti_8$ (base alloy), TiO_2 and Y_2O_3 dispersed base alloy sintered at different temperature

Wear study

From 2 (a, b) shows the variation of wear depth with sliding time of $Al_{70}Cu_{22}Ti_8$ (base alloy), Y_2O_3 and TiO_2 dispersed base alloy sintered at 900 and 1100°C respectively. It is observed from both graphs that the wear depth decreases with the addition of Y_2O_3 and TiO_2 to the base alloy. The reason is that hard and brittle TiO_2 and Y_2O_3 spread all over the intermetallic uniformly and reduces the pores and providing strong interfacial bond. Watanabe et al. studied the wear behaviour of $Al\text{-}Al_3Ti$ composite and showed that wear resistance is more for the composite as compared to pure Al. The abrasion is the main mechanism of wear on $Al\text{-}Al_3Ti$ composite. The found that the supersaturated Al_3Ti layer formation occurs from the top surface to 100μm depth. It is seen from the graphs that samples sintered at 1100°C shows more wear resistance than 1000°C due to higher hardness. The maximum wear depth of base alloy sintered at 1100°C is around 200μm, whereas wear depth is 340μm for base alloy sintered at 900°C. This is due to higher hardness at 1100°C as compared to 900°C.



(a) (b)

Figure -2 (a) and (b) Variation of wear depth with sliding time of $Al_{70}Cu_{22}Ti_8$ (base alloy), Y_2O_3 and TiO_2 dispersed base alloy sintered at 900 and 1100°C.

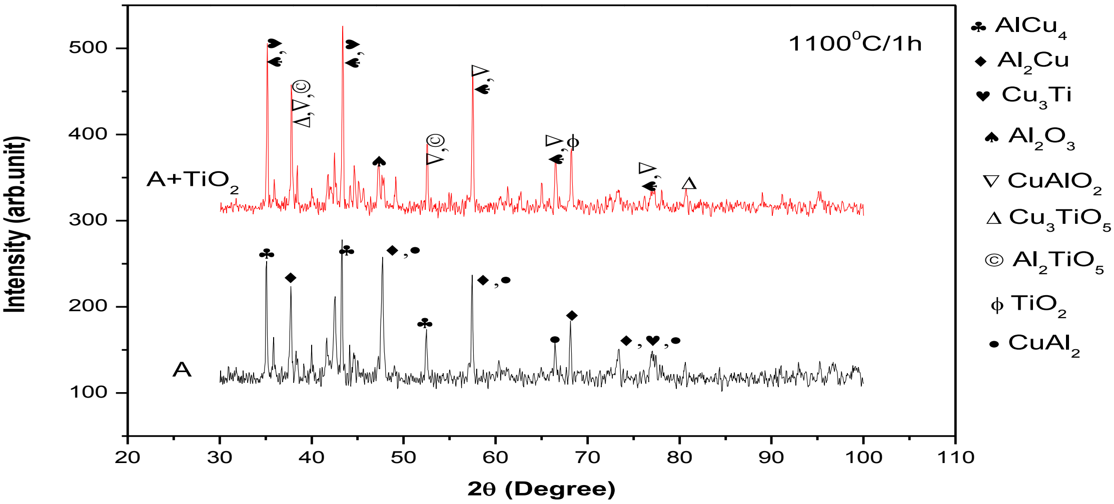


Figure-3 XRD spectrum of base power of composition $Al_{70}Cu_{22}Ti_8$ and Y_2O_3, TiO_2 dispersed intermetallic at 1100^0C for 1 h

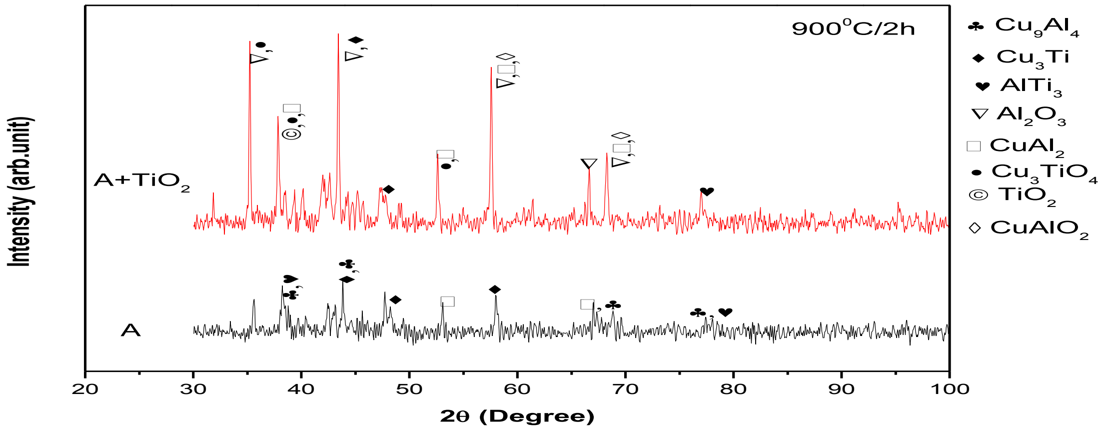


Figure-4 XRD spectrums of base powder of composition $Al_{70}Cu_{22}Ti_8$ and TiO_2 dispersed intermetallic at 900^0C for 2 h.

Figure -3 shows that XRD spectra of 50h milled base power $Al_{70}Cu_{22}Ti_8$, TiO_2 dispersed base powder sintered at 1100 for 1h under argon atmosphere. In base sample the peaks of $AlCu_4$ and $CuAl_2$ peaks are visible. Here, aluminium reacts with Copper to form these above compounds. XRD spectra show the peaks of Al_2O_3, Cu_3TiO_5, $CuAlO_2$ and $CuTi_3$. Formation of these above compounds may be possible due to the reaction of TiO2 with Cu and Al.

Figure -4shows the XRD spectra of 50h milled base powder $Al_{70}Cu_{22}Ti_8$ and TiO2 dispersed base powder sintered at 900^0C for 2h under argon atmosphere. It is found that there is a formation of Cu_9Al_4, Cu_3Ti and $CuAl_2$intermetallics for the base composition after sintering. Formation of Al_2O_3 and Cu_3TiO_4 is evident from XRD spectrum due to reaction of TiO2 with base sample after sintering.

CONCLUSIONS

This study explored the characterization of ball-milled Al-alloy powder and reported the effect of milling and phase formation techniques to study the characteristics of alloy powder. The following important findings derived from the results were presented in this paper.

A maximum Vickers microhardness of 449, 649, 872HV were obtained for base alloy, Y_2O_3 and TiO_2 dispersed alloy sintered at 1100°C for 1h respectively. It was also found that TiO_2 and Y_2O_3 dispersed base alloy have higher wear resistance than base alloy.The XRD study shows the peaks of Cu_2Al_4, AlCu, $AlTi_3$intermetallic phases after 50 h of milling in case of base alloy. After consolidation of the base alloy, formation of new phases like Cu_9Al_4, Cu_3Ti, $CuAl_2$ are visible for the alloy sintered at 900 and 1000^0C but phases like Al_2Cu, $AlCu_4$ also visible for sintering at 1100^0C. After addition of TiO_2 and Y_2O_3 in base alloy there is formation of Al_2O_3.

REFERENCES

[1] Schweitzer P.A.,"MetallicMaterials, Physical, Mechanical and Corrosion Properties", CRC Press (2003)
[2] CallisterW.D.,"Material Science and Engineering" 7th edition ,John Wiley and Sons, University of Utah, (2007) pp. 577-578
[3] SauthoffG.,"Intermetallic" ,Chapman & Hall ,New york
[4] Mikkola D.E., Nic J.P., Zhang S., Milligan W.W.,The Iron and Steel Institute of Japan international,1991;31:1076
[5]Kumar K.S., Darolia R., Lewandowski J.J., Liu C.T., Martin P.L.,Miracle D.B., Nathal M.V., editors," Structural intermetallics",Warrendale, USA: TMS; 1993. p. 87–96
[6]Varin R.A., Winnicka M.B., Virk I.S., In: Darolia R., Lewandowski J.J.,Liu C.T., Martin P.L., Miracle D.B., Nathal M.V., editors. Structural intermetallics.Warrendale, USA: TMS; 1993. p. 117–24
[7] Shull R.D.,Nanostruct Mater 1993;2:213
[8] Moon K.I., Chang K.Y., Lee K.S.J., Alloys Comp 2000;312:273
[9]Anton D.L., Duhn D.N., Giamci A.F.J, Miner Metals Mater Soc 1989;41:12
[10]Nayak S.S., Murty B.S.," Synthesis and stability of L12–Al3Ti by mechanical alloying" , Materials Science and Engineering A 367 (2004) 218–224
[11] Yamaguchi M.,UmakoshiY.,YamaneT., Phil. Mag. 55 (1987) 301.