International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 03, March-2023

A Novel Foil Developed with Cu-Ag-Ti for Joining Alumina Ceramic and Titanium Alloy: Development and Characterization

Mohan H S
Research scholar, Dept. of Mechanical Engineering
AMC, Bangalore, Karnataka, India

Anil K C
Dept. Industrial Engineering & Management
Siddaganga Institute of Technology, Karnataka, India

T. P. Bharathesh
Professor, Dept. of Mechanical Engineering
Akshaya Institute of Technology, Karnataka, India

K.V. Sreenivas Rao
Professor & Principal
Akshaya Institute of Technology, Karnataka, India

***Abstract*— Active brazing is a preferred technique for joining materials such as ceramics or composites and metal in practical engineering. It is highly versatile due to its adaptability to various joint sizes and shapes. The joints are subjected to annealing at 800°C, 850°C, and 900°C, keeping the soaking time and ramp rate constant. After heat treatment, the samples are well polished and subjected to morphological studies using SEM. An attempt has been made to modify the Ag-Cu brazing alloy using Ti element to join ceramic to metal or ceramic components. The Ti factor has been added to foil to enhance to its Wettability and bonding properties. EDX, SEM and Optical microscope are used for the prepared foil characterization.**

***Keywords*— Alumina, Brazing, Ceramic, SEM, Sliver – Copper.**

I. INTRODUCTION

Ceramics are utilised in batteries, integrated circuits, cutting tools, and biomaterials, as well as in the electrical, aerospace, nuclear, and automotive industries. Dissimilar metals are difficult to connect with standard fusion welding due to their chemical and physical differences. Solid state joining techniques have attracted a lot of attention in this regard. Titanium alloy was brazed using Ag-Cu filler metal with no active element [11]. It was also said that the Ag-Cu metal was utilised in the braze process because the dissolution of titanium alloy created Ti as the active element to react with the C/C composite [12].

Advanced ceramics are becoming more widely used in engineering, from microelectronic circuits to automotive and aero engine applications. It is frequently important to attach ceramic pieces to other materials, particularly metals, in order to get the best performance out of specific components. Because of the inherent characteristics of most ceramics, fusion welding is almost impossible. Solid state methods, adhesive bonding, and brazing, on the other hand, remain viable options for creating strong, reliable junctions between ceramics and metals.

The disparity in thermal expansion coefficients of the two materials is the most problematic aspect of metal to ceramic bonding. When this discrepancy is paired with the rigidity of the ceramics, destructively large strains are formed in the joint zone. Keeping the joining temperature as low as feasible is an effective technique to reduce this thermal mismatch. Nearly all of the ceramics are wet during the Ag-Cu-Ti process [10], which results in strong joints. The prepared foil is characterized using EDX, SEM, and an optical microscope.

In a variety of industrial applications, the connecting of different materials is becoming increasingly crucial. High-performance components, such as those with a good strength-to- weight ratio, high electrical/thermal conductivity, increased corrosion resistance, or high temperature strength, are required for pioneering constructions, which can only be achieved by combining different materials [2].

The plastic response of the filler metal determines how much residual tension is relieved in ceramic-metal junctions created by active brazing [5]. RAB (reactive air brazing) is a new technique for making ceramic-to-ceramic and ceramic-to-metal junctions. RAB was explored in this work with regard to prospective applications for solid oxide fuel cells (SOFCs), as one example. RAB was discovered to be capable of brazing alumina using Ag-Cu and Ag-CuTi brazes.

The wetting behavior and mechanism of wetting were strongly impacted by both braze content and brazing temperature [8]. Vacuum brazing with Ag–Cu–Ti active filler metal effectively brazed composites and TC4 alloy. A scanning electron microscope, an energy dispersive spectrometer, and X-ray diffraction were used to examine the interfacial microstructure. The impact of brazing temperature on the interfacial microstructure and joint characteristics was thoroughly examined. The brazed joints created a variety of phases, including TiC, TiSi2, Ti3Cu4, Cu, Ag, TiCu, and Ti2Cu. The interfacial microstructure changes dramatically as the brazing temperature rises, whereas the amount of Ti2Cu decreases but no new phase is formed [11].

By offsetting the tool to the aluminum side and friction stir welding aluminium and copper plates, excellent metallurgical bonding was achieved on the Al–Cu interface, resulting in the development of a thin, continuous, and homogeneous Al–Cu intermetallic compound (IMC) layer [1].It has also been reported that an Ag–Cu filler metal with no active element was used to braze a C/C composite and titanium alloy, because the dissolution of titanium alloy provided Ti as a result of the dissolution. The substance that will react with the C/C compound [3].

Brazing offers high joint strength (close to or equal to that of the ceramic), a high service temperature, excellent thermal and electrical conductivity, excellent tightness, and moderate costs among the various bonding techniques. Due to the fact that commercial filler metals do not wet ceramics, metallization of the ceramic surface is necessary, followed by a reaction. Thermal treatment is commonly used. Direct or active brazing was created to make brazed ceramic joints easier to make: the filler metal contains an active element (such as Ti) that encourages effective wetting of the ceramic surface and removes the need for metallization treatments. Because reactive materials want oxygen, active brazing takes place in a vacuum furnace [7].

II. EXPERIMENTAL PROCEDURE

A. Casting process

In present investigation Silver (70%), Copper (28%) and Titanium (2%) are used for the preparation for preparation of foil. Foil is prepared by placing the Materials in the graphite crucible to make the cast as shown in the fig.1.

(a)

(b)

Fig. 1. Casting process of filler material (a) Pit furnace and (b) Solidified cast

(a)

(b)

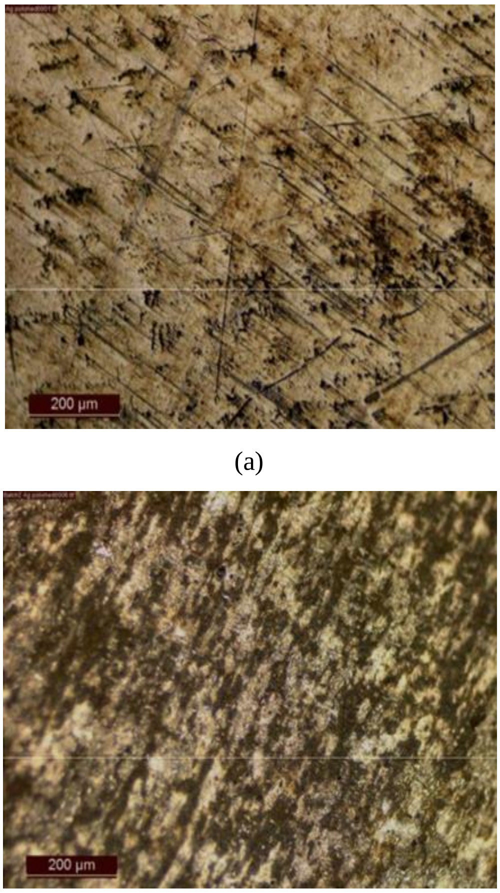
Fig. 2. (a) Rolling machine and (b) Finished filler material

The titanium powder is added to the crucible after the components have been transformed into molten metal and swirled until the alloy is perfectly blended. The molten metal was taken from the furnace and poured into the mould after being held for 15 minutes for homogeneity. The rolling machine is used to reduce the thickness of the material by forcing the solidified sample to travel between two rollers, reducing the thickness of the sample by 5 mm. The sample is then heated in an electric furnace until it reaches a temperature of 550 °C, at this point it is removed. The process is then repeated by placing it in a roller. This sample is made up of a filler material with thicknesses of 0.1 mm, 0.15 mm, and 0.2 mm and a width of 25 mm as shown in fig. 2.

III. CHARACTERIZATION OF AG-CU-TI FOIL

A. Microstructural analysis.

The microstructure and chemical composition of the sample were examined using a Leica Micro-system optical microscope and a JAOL scanning electron microscope. Optical Microscopy (OM), and Energy Dispersive X-Ray Spectroscopy (EDX) were also employed in the study. Cast copper, silver, and titanium alloy XRD analysis Cu_2Ti, Cu_2Ti_4, Ti_3Cu, Cu-Ag-Ti, and Ag-Ti are the phases that may be seen using XRD on the active materials. The electron beam hits the inner shell of an atom, knocking an electron out and leaving a positively charged electron hole as shown in fig 4.



(a)

(b)

Fig. 3. Microscopic Image of Ag-Cu-Ti filler material (a) without (b) with etching respectively

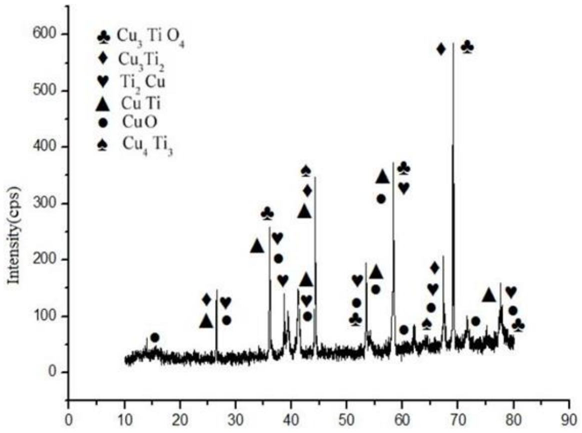
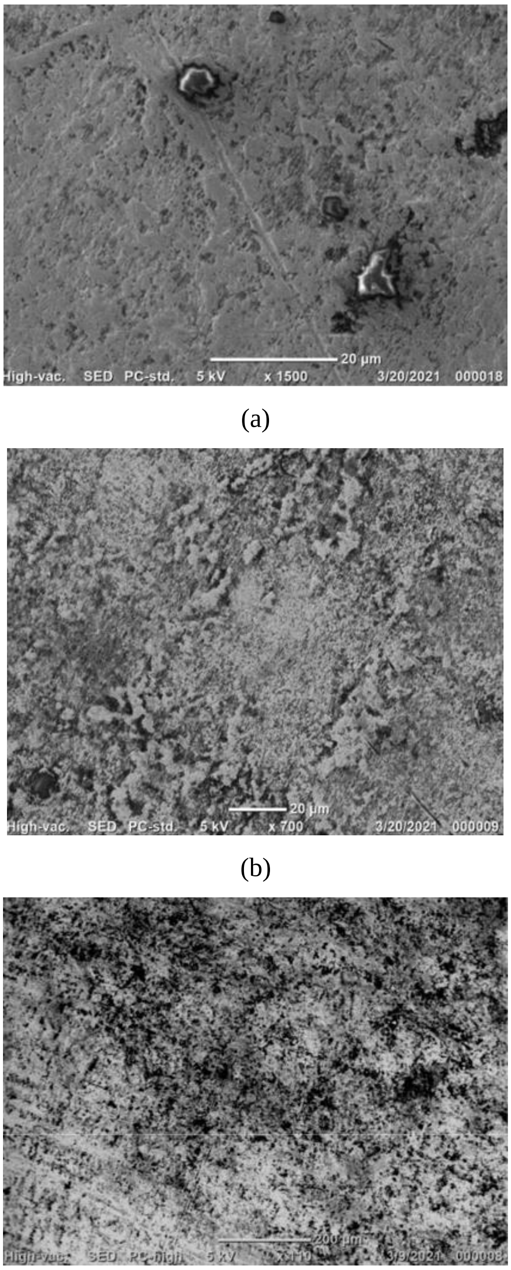


Fig. 4. XRD patterns of interface of Ag-Cu-Ti foil.

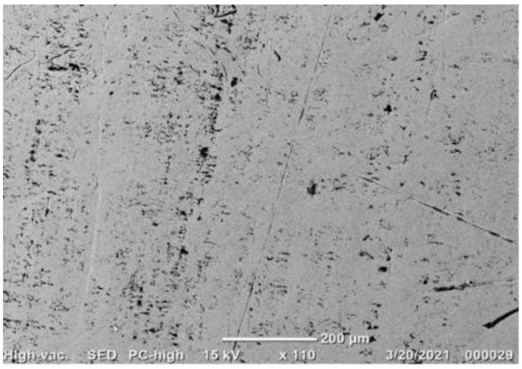
Scanning electron microscope (SEM) creates an image by scanning a focused electron beam across a surface. The electrons in the beam interact with the sample, generating a variety of signals that can be utilized to study the surface topography and composition. figure 5 displays SEM examination at several locations with and unpolished surfaces. Dendrites, eutectic, and intermetallic compounds including CU_2Ti and Ag Ti correspondingly make up the microstructure of Ag-Cu-Ti filler. Ag filler is used to make dendrites, with a small amount of Cu and Ti thrown in for good measure. Using a constant stream of etching reagent (NH_4OH: H_2O_2: H_3M) up to 0.5 wt%. Titanium is 67 percent soluble in copper at 1150°C, but only 3 percent soluble in silver at the same temperature which gives the possibility of easy joining. SEM and EDX analysis reveal the presence of Ti, Ag, Cu. During SEM studies, two types of phases with different restrictions are found, regardless of the amount of Ag and Cu present in the alloys. Figure 6 displays a SEM image of copper, silver, and titanium in an effort to develop copper, silver, and titanium. Diffusion bonding occurs between copper, silver, and titanium, as evidenced by the image. The active element Ti must dissolve with copper and silver, according to an XRD study of the filler foil



(a)

(b)

(c)



(d)

Fig. 5: SEM Images of Ag-Cu-Ti filler material (a)Foil without etching, (b)Foil with etching, (c)Foil before polishing, (d) Foil after polishing respectively.

B. *Wetability analysis*

Wetting is the ability of a liquid to retain contact with a solid surface when the two are brought together due to intermolecular interaction. A force balance between adhesive and cohesive forces determines the degree of wetness. A drop spreads across the surface due to the adhesive force between a liquid and a solid. The drop balls rise due to cohesive forces inside the liquid, avoiding contact with the surface. The addition of up to 0.5 wt.% etchant to the Ag-Cu-Ti filler material results in a considerable increase in spreading area as shown in Table.1

The oxydo-reduction process is commonly used to discuss reactivity in pure reactive metaloxyde systems. We'll look at the situation of reducing alumina with a metal M and forming a MO oxide, as described in the following Eq. (1).

$$\frac{3}{2}(M)+\frac{1}{2}Al_2O_3 \leftrightarrow \frac{3}{2}MO+(Al) \qquad (1)$$

Calculating the equilibrium concentration of Al in liquid M, resulting from the dissolution of Al, O can be used to determine the degree of advancement of the interfacial Eq. (1). This degree of development is equal to the difference between the final and beginning mole fractions of Al, X, (which in our case is zero). In the case where X << 1. The equilibrium X, for Eq. (2) is stated as follows

$$X_{Al} = \exp-\left(\frac{\Delta G_R^*}{R.T}\right) \qquad (2)$$

As will be seen further, the term ΔGR*/R.T is used to establish a rough scale of relative reactivity for different systems.

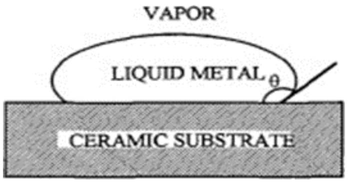


Fig. 6. Definition of the contact angle θ of a liquid on a flat surface.

There is currently no universal acceptance theory capable of satisfactorily characterizing reactive wetting, such as wetting followed by material transfer at the solid-liquid interface. The smallest contact angle (as indicated in figure 1) feasible in a reactive system, according to LAURENT, is provided by Eq. (3).

$$\cos\theta_{min} = \cos\theta_0 - \frac{\Delta\sigma_r}{\sigma_{LV}} - \frac{\Delta G_r}{\sigma_{LV}} \qquad (3)$$

Where $\theta 0$ is the contact angle of the liquid on the substrate in the absence of any reaction and σLV is the interfacial energy between the liquid and the vapor phase. Δσr, takes into account the change in interfacial energies brought by the interfacial reaction. ΔGr is the change in free energy per unit area, released by the reaction of the material contained in the "immediate vicinity of the metal-substrate interface"

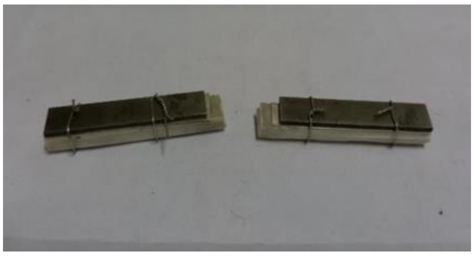
Adding a solute, such as titanium, to a non-reactive metal improves wetting significantly, resulting in in situ change of both the liquid and solid sides of the interface. If this solute develops strong solute-solute interactions with dissolved oxygen, such an improvement will be conceivable.

Table.1 Wetting angle of Ag-Cu-Ti filler material

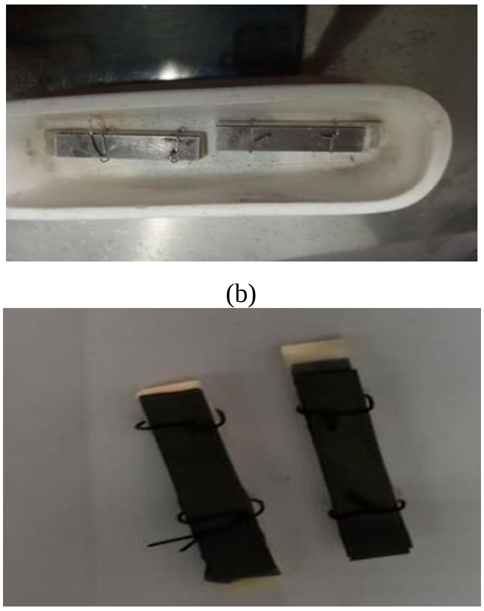
Contact angle	**Degree of wetting**	**Strength**	
		Sol/Liq interaction	***Sol/Liq interaction***
Θ=0°	Perfect wetting	Strong	Weak
0<Θ<90°	High wettability	Strong/Weak	Strong/Weak
90º ≤θ<180°	Low wettability	Weak	Strong
Θ = 180°	Perfect non wetting	Weak	Strong

IV. BRAZED JOINT

Before brazing Ceramic is Cutted in to 0.7mm through laser cut method, Titanium is cutted in to 0.7mm through EDM method and alloy is cutted in to 0.7mm manually. Ceramic, alloy, titanium is placed one over the other and tied with steel wire. Alloy is sandwiched between ceramic and titanium are connected together with steel wire and maintained in a quartz tube in a vacuum chamber for brazing and subjected to three different brazing temperature of 800°C,850°C, 900°C, After the brazing components have been removed from the vacuum chamber, the steel wires have been removed, and the joint surface has been roughed, SEM images are collected and examined. The stages of brazing is as shown in the fig.7.



(a)

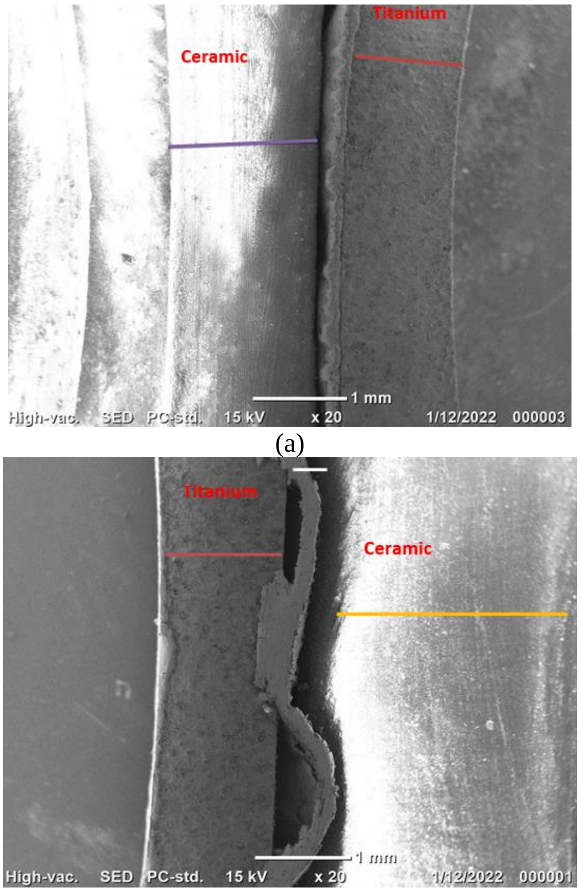


(b)

(c)

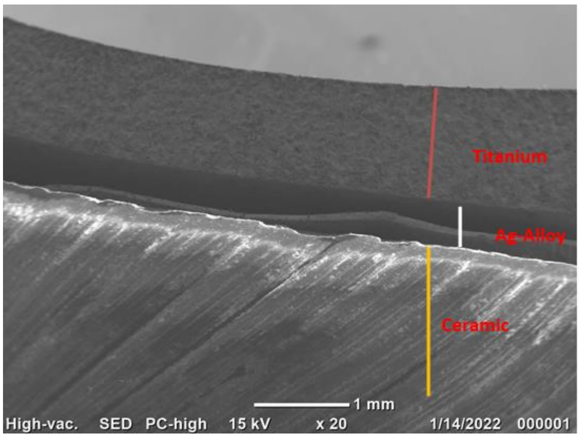
Fig. 7: stages in brazing of Alumina – KM76- Titanium joint.

A. *SEM analysis of brazed joints*



(a)

(b)



(c)

Fig.8: Brazed joints are subjected to brazing at (a) 800°C, (b) 850°C, and (c) 900°C, keeping the soaking time and ramp rate constant

Fig. 8 show the joints are subjected to brazing at 800°C, 850°C, and 900°C, keeping the soaking time and ramp rate constant. After brazing, the samples are well polished and subjected to morphological studies using SEM. The results are tabulated above. There were no micro-cracks or micro-holes developed in the brazed joint, as shown in the SEM image. The 800°C brazed sample has better connectivity. When the alloy is fused in a straight line at a micron scale level, this induces connectivity over the entire length of the joint. Whereas with increasing temperatures, the Ag- alloy melts better, it loses its original shape due to complete melting at elevated temperatures. As the other conditions for heat treatment are kept constant, we believe the temperature is the crucial factor in obtaining a uniform melt and better connectivity. The solidus temperature and liquidus temperature of Ag–Cu–Ti alloy are 766°C Cand 817°C respectively.

V. CONCLUSION

In conclusion, the Stir Casting Method can be used to produce new Ag-Cu-Ti filler materials, which can be rolled into foils of varying thicknesses up to 0.05mm. This method is efficient, with a high output rate and can be carried out at temperatures of up to 1200°C. Preheating is necessary for the rolling action, and SEM, EDX, and XRD characterization investigations have been carried out. The observed elements and phases in the active filler materials are very similar, including Cu, Ag, and Ti. The XRD results show that Cu_2Ti, Cu_2Ti_4, Ti_3Cu, CuAgTi, AgTi are the phases present in the filler materials. Finally, the temperature is a crucial factor in obtaining a uniform melt and better connectivity

REFERENCES

[1] P. Xue, B.L.Xiao, D.R.Ni, Z.Y.Ma*, “Enhanced mechanical properties of friction stir welded dissimilar Al-Cu joint by intermetallic compounds” Materials Science and Engineering A 527 (2010) 5723-5727.

[2] I.V. Oliveira, A.J. Cavaleiro, G.A. Taber and A. Reis, “Magnetic Pulse Welding of Dissimilar Materials: Aluminum-Copper” Materials Design and Application, Advanced Structured Materials 65, DOI 10.1007/978-3-319-50784-2_31 AG 2017.

[3] Zhitao Hao, Dongpo Wang, Zhenwen Yang*, Ying Wang, “Microstructure and Mechanical properties and C/C composite joints brazed with Ag-Cu-Zn and Ag-Cu- Zn/Cu/Ag-Cu-Ti filler metals” Archives of civil and mechanical engineering 19 (2019) 1083-1094.

[4] I.Sudmeyer, T.Hettesheimer, M.Rohde, "On the shear strength of laser brazed SIC- Steel joints: Effects of brazed metal fillers and surface patterning" Ceramics International,36 (2010) pp.1083-1090.

[5] MatteoGalli, John Botsis, "Characterization of the Residual Stress and Strength of Ceramic-Metal Braze Joints" Journal of Engineering Material and Technology, 131 (2009) pp. 021004-1.

[6] W.Lippmann, J.Jnorr, R.Wolf, R.Wolf, R.Raper, H.Exner, A.M.Reinecke, M.Nieher, R.Schreiber, "Laser joining of silicon carbide-a new technology for ultra-high temperature resistant joints" Nuclear Engineering and Design, 231 (2004) pp.15-161.

[7] F.Moret and N.Eustathopoulos, "Ceramic to metal direct brazing" Journal De Physique IV, (1993) pp.1043-1052.

[8] Kirsten Bobzin, Thomas Schlaefer, Lidong Zhao, Nils Kop, Arne SchlegeL,"Brazing of ceramic-to-ceramic and ceramic-to-metal joints in air" Front. Mtech. Eng. China 2010, 5(2), pp 125-129.

[9] Anil, K. C., Sachin Gadge, Rishabh Kumar Srivastva, and K. V. Sreenivas Rao. "Three-body abrasive wear behavior of Al-8011 alloy reinforced with graphite and red mud particulates." Int. J. of Science, Engineering and Management (IJSEM) 2, no. 2 (2017).

[10] Wolfgang Lippmamm, Jurgen Knorr, Regine wolf, Anne-Maria Reinecke, Roland RalandRasper, " Laser Beam Joining of Non-Oxide Ceramics for Ultra High Temperature Resistant Joints" 14th International Symposium on the packaging and Transportation of Radioactive Materials, Berlin, Germany, September 2004, pp.

[11] Y Liu, ZR Huang, XJ Liu, " Joining of sintered silicon carbide using ternary Ag-Cu-Ti active brazing alloy", Ceramics International 35 (8), 3479-3484, 2009.

[12] K.V. Sreenivas Rao, K.C. Anil, Akash, K.G. Girisha, Effect of Particle Size on Mechanical Properties of Al-RMp Metal Matrix Composites, Materials Today: Proceedings, Volume 4, Issue 10, 2017, Pages 11154-11157, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2017.08.080.

[13] D Liu, HW Niu, YH Zhou, XG Song, DY Tang, JC Feng, " Brazing continuous carbon fiber reinforced Li2O-Al2O3-SiO2 ceramic matrix composites to Ti-6Al-4V alloy using Ag-Cu-Ti active filler metal", Materials & Design 87, 42-48, 2015.

[14] Akash, K.Chikkanna Anil, K.G. Girisha, and K.V. Sreenivas Rao. "Effect of Fibre Orientation on Specific Gravity, Hardness, Flexural Strength and Tensile Properties of Jute/Hemp Hybrid Laminate Composite." Applied Mechanics and Materials. Trans Tech Publications, Ltd., June 2015. https://doi.org/10.4028/www.scientific.net/amm.766-767.75

[15] Anil , K. C., Hemavathi, A. and Adeebpasha, A. (2023) "Mechanical and Fractured surface characterization of epoxy/red mud/fly ash/ aluminium powder filled hybrid composites for automotive applications", Frattura ed Integrità Strutturale, 17(64), pp. 93–103. doi: 10.3221/IGF-ESIS.64.06.

[16] Yoshihisa Sechi, Takuya Tsumura, Kazuhiro Nakata,"Dissimilar laser brazing of boron nitride and tungsten carbide" Materials and Design, 31 (2010) pp. 2071-2077.

[17] J. Kumaraswamy, K.C. Anil, Vidyasagar Shetty, Development of Ni-Cu based alloy hybrid composites through induction furnace casting, Materials Today: Proceedings, Volume 72, Part 4, 2023, Pages 2268-2274, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2022.09.215.

[18] B. Latha Shankar, P.M. Nagaraj, K.C. Anil, Optimization of Wear Behaviour of AA8011-Gr Composite using Taguchi Technique, Materials Today: Proceedings, Volume 4, Issue 10, 2017, Pages 10739-10745, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2017.08.021

[19] Girisha, K.G., C. Durga Prasad, K.C. Anil, and K.V. Sreenivas Rao. "Dry Sliding Wear Behaviour of Al<Sub>2</Sub>O<Sub>3</Sub> Coatings for AISI 410 Grade Stainless Steel." Applied Mechanics and Materials. Trans Tech Publications, Ltd., June 2015. https://doi.org/10.4028/www.scientific.net/amm.766-767.585.

[20] K.C. Anil, J. Kumaraswamy, Akash, S. Sanman, Experimental arrangement for estimation of metal-mold boundary heat flux during gravity chill casting, Materials Today: Proceedings, Volume 72, Part 4,

[21] 2023, Pages 2013-2020, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2022.07.399.

[22] Harishchandra et al 2016 IOP Conf. Ser.: Mater. Sci. Eng. 149 012026, DOI 10.1088/1757-899X/149/1/012026.

[23] Girisha, K.G., R. Rakesh, K.C. Anil, and K.V. Sreenivas Rao. "Dry Sliding Wear Behavior of Ni-Cr/Micro-ZrO<Sub>2</Sub> Coated AISI 410 Grade Steel-Final Revision." Applied Mechanics and Materials. Trans Tech Publications, Ltd., August 28, 2015. https://doi.org/10.4028/www.scientific.net/amm.787.454.

[24] Adaveesh, B., K.C. Anil, M. Vishwas, and R.P. Archana. "Development and Property Evaluation of Fiber Reinforced Hybrid Epoxy Laminate Composite: Jute/E-Glass/Carbon-Fabric-Final Revision." Applied Mechanics and Materials. Trans Tech Publications, Ltd., August 28, 2015. https://doi.org/10.4028/www.scientific.net/amm.787.534.

[25] S, S., K P, P., K C, A., B K, V., U B, G. K., & L, Y. (2022). Effect of percentage of reinforcement particulates on the corrosion behaviour of aluminium boron carbide composites. Journal of Mines, Metals and Fuels, 69(12A), 250–254. https://doi.org/10.18311/jmmf/2021/30111.