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Current Research Trends in Aluminium Metal Matrix Composites–A Review

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Abstract—*Aluminium based Metal matrix composites (AMC) are gaining significant interest within the application field of aerospace, automobile and sports equipment manufacturing industries, due to their interesting mechanical and material properties viz. high strength, high stiffness, damping capacity, reduced density and improved abrasion and wear resistance capacity compared to unreinforced alloy. This paper presents the overview on the effects of different reinforcements in Aluminium and its alloy and focused on different synthesis techniques of AMCs. Affect of reinforcement on the microstructure and mechanical properties like tensile strength, compressive strength, ductility, hardness and wear and corrosion rate are also discussed in details. The defects associated with the casting of AMCs such as formation of intermetallic compounds, agglomerating phenomenon, presence of voids and cracks on the microstructure, poor wettability and high fabrication costs are also dealing in this paper. Furthermore, the machinability of the AMCs is highlighted on the basis of the machining process parameters and variation of the reinforcement in the composites.*

Keywords*: composites, metal matrix, microstructure, corrosion,*

1. INTRODUCTION

In recent scenario Metal matrix composites have tremendously increasing demand due to its favorable mechanical and material properties. Therefore it is prerequisite to select proper reinforcing material and methodology to achieve higher performance of MMCs and simultaneously essential to picking the economical fabrication route. However, it is also important to evaluate the optimum machining conditions to achieve superior machining performance of the MMCs [46]. Liquid state method is more preferable over solid state method due to simplicity, capable of mass production and ease of adoption [40]. Stir casting method is widely used during fabrication of MMCs, because it is simple, effective and economical process. However, improving the casting grade during stir casting process, different methods were attempt to made such as reinforcement particles were preheated to enhancing the wettability [41]; additionally introduce wettability agents [1,42] and fluxes [43]; coated [44] and wrapped [5] the filler material particles which provided better mixing between ceramic particle and molten alloy matrix. Inexpensive fly ash is used as a reinforcing material to minimize the cost of fabrication and it is available in large quantities in thermal power plants [38,39]. Degasser agents are used for avoiding voids in the microstructure of the composite [2]. Ceramic content initiated and spread the pitting corrosion on the surface of the composite compared to the unreinforced metal matrix [10]. Due to the abrasive nature of the reinforcement particles it is difficult to machining of the MMCs in traditional machine [31-32]. EDM has the potential to effective machining of the MMCs [33-35]. WEDM machining process is effective and economical for machining of MMCs. It has capacity to produce complicated shapes with high accuracy [36,37].

2. FLY ASH REINFORCED AMC

Anilkumar et al [1] fabricated Fly Ash Reinforced Aluminium Alloy (Al6061) Composite samples by using stir casting method and investigated various mechanical properties. They found that as the percentage of fly ash reinforced increased in the composite tensile strength, compressive strength and hardness were also increased but the ductility was decrease. The micrograph of SEM was symbolized that fly ash particles were uniformly embedded into the alloy matrix and exhibited good bonding between fly ash and Al alloy. Mahendra and Radhakrishna [2] synthesized Al–4.5% Cu alloy with fly ash metal matrix composite samples by stir casting route. They were considered different tests on the prepared samples and found that as the wt. fraction of the fly ash ceramic particles were enhancing in the specimens then hardness, impact strength, dry sliding wear, slurry erosive wear, and corrosion were increased while density and fluidity were decreased. Sudarshan and Surappa [3] investigated the prepared fly ash particle reinforced A356 Al composite samples with narrow size range (53-106μm) and wide size range (0.5- 400μm) of the fly ash particles. They were studied the characterization of the samples and established that the narrow size range of fly ash reinforced AMCs were exhibited better mechanical properties as well as microstructures than the large size range of fly ash reinforced AMCs. They analyzed the microstructure in SEM and established that hot extrusion improves integrity of the microstructure. Also Thermodynamic analysis revealed that there was chemical reaction possible between fly ash particles and molten alloy. Selvam et al [4] considered compocasting process to synthesis AA6061/fly ash composite. The XRD peaks of the prepared composites showed that all the integrity of fly ash were preserved and the interfacial reaction between fly ash and alloy matrix was successfully avoid during the compocasting process. Therefore compocasting method was illustrated better mechanical and tribological properties than stir casting method. Also from the optical and SEM micrograph it was evident that high aspect ratio dendric arms were existed in the microstructure due to solidification. More over casting standard was superior and eliminated the common casting defects such as porosity, shrinkage or slag inclusion. It is signifying as Economic method, since it has not required any degasser and wettability reagents. Murthy et al [5] prepared aluminum–fly ash nano composite samples by using high energy ball milling process, vortex method and ultrasonic cavitation method. They illustrated from the SEM study that the applied ball milling method demolished the spherical structure of the fly ash particles and it became reducing nano size. Also nano reinforced particles were uniformly dispersed into the matrix alloy and no additional contamination was existed. The compression strength and hardness of the prepared nano composites were enhancing after addition of nano fly ash particles and pure aluminium powder. Udaya Prakash et al. [6] showed the fabrication Wire EDM machinability of Aluminium alloy (A413)/Fly ash/B_4C Hybrid composites. They illustrated that Gap voltage and wire feed are found to be the most influential parameters.

3. SILICON CARBIDE REINFORCED AMC

Tamer Ozben et al. [7] evaluated the mechanical property and machinability of SiC particle reinforced AMC. They found as the increasing of silicon carbide reinforcement; tensile strength, hardness and density of the composites were also increased, but impact toughness was decreased. Also it was difficult to machining of SiC particle reinforced AMC in traditional machine due to the abrasive nature of the AMCs. Tzamtzis et al. [8] suggested the Rheo- processing route for synthesis of Al/SiC particulate MMCs over conventional processing methods. Because conventional processing methods like stir casting technique exhibited undesirable agglomerating effects, non homogeneous reinforcement distribution in the matrix alloy and poor wettability between ceramic particles and molten alloy. As a result casting quality and mechanical properties are degrading. However, Rheo-processing method overcomes those processing defects under application of sufficient amount of shear stress during incorporation of particulate clusters and liquid matrix metal. Yanming and Zhou [9] investigated the tool wear and its mechanism for cutting SiC reinforced AMC. They found from the experimental results that the volume fraction of SiC and its particle size are the major factors to affecting the tool life. They concluded that the abrasive wear was taking placed on the tool flank edge in conventional tools and when machining of the composite materials, the tool life was decreased due to the brittle failure. Sedat Ozdenet et al. [10] investigated the impact behavior of Al and SiC particle reinforced with AMC under different temperature conditions. Clustering of particles, particle cracking and weak matrix-reinforcement bonding were the major factors that affected the impact behavior of the composite. Li et al. [11] fabricated CNT-covered micro-sized SiCp hybrid reinforced Al matrix composites by conventional powder metallurgy (PM). The nano size CNT and the micro size SiC particles were integrated through In-situ CVD process and formed nano/micro-sized Hybrid composite. They evaluated that CNT homogeneously distributed in Al alloy matrix with the help of micro size SiC particles act as a vehicle and also the prepared hybrid composite exhibited good mechanical properties. Adem Onat [12] fabricated Al–4.5Cu–3Mg/15 vol. % SiCp matrix composites by using squeeze casting technique. The microstructure of the prepared composites evinced good interfacial bonding and uniformly distributed porosity free SiC particles into the matrix alloy. It was revealed on the basis of the experimental results that as the applied load and sliding speed increased, the friction coefficient of the composites was decreased. Analysis of SEM results at worn surface generalized that it consisted of plastically deformed and oxidized particles removed by the micro-machining effects of the reinforcement phase. Rana et al. [13] investigated tribological behaviour of AA 5083/Micron and Nano SiC composites fabricated by ultrasonic assisted stir casting process. They evaluated that under low load and smaller sliding distance composites with nano SiC exhibited higher wear resistance and under high load and longer sliding distance composites with micron SiC presented higher wear resistance. Narayana Murty et al. [14] examined the characterization of 6061A- SiC and 6061- Al_2O_3 particulate reinforced metal matrix composites. They illustrated that high strain rate region which contain high values of mass should be more preferable during bulk working operations and the lower strain rate regions are suitable during secondary metal working operations.

4. BORON CARBIDE REINFORCED AMC

Onoro et al. [15] studied the mechanical properties of the 6061 and 7015 composites reinforced with B_4C particles under high temperature. They established that as the addition of B_4C particles in the both matrices of aluminium 6061 and 7015 provided improve mechanical behavior. However the B_4Cp reinforced composites and the unreinforced Aluminium 6061 and 7015 alloys were carried decreasing tensile strength as the increased of temperature. But the ductility was increased along the increasing test temperature. Cun-Zhu et al. [16] studied the microstructure and the mechanical properties of the B_4Cp/2024Al composite assisted by the OM, SEM and TEM analysis. They used mechanical alloying–hot extrusion technology to prepared B_4Cp/2024Al composites. It revealed that the prepared composites had improved mechanical properties after addition of B_4C particles. From the morphological point of view, it exhibited good microstructure properties such as uniformly distribution of the B_4C particles into the alloy matrix, no chemical compounds formed near the interface and strong interface bonding between B_4C particles and 2024Al alloy. Ahamed et al. [17] investigated the effects of machining process parameters viz current, pulse on time, pulse off time and flushing pressure on the MRR and surface roughness during machining of hybrid composites Al–5%SiC–5% B_4C sample and Al–5%SiC–5% Glass sample by using of EDM machine. They established that the ceramic particles obstructed to machining process. Also, by balancing of levels of the process parameters it can be possible to obtain maximum MRR at minimum surface roughness of the both composite samples. Kalaiselvan [18] investigated the effect of FSW on microstructure and mechanical properties of AA6061/12 wt. % B_4C AMC. They examined the weld zone of the composites on the basis of SEM study and found that fine grains and homogeneous distribution of B_4C particles were dispersed on the welding region. Moreover, the hardness of the weld zone was higher than that of the parent composite. Also it was revealed that the FSW reduced the ductility of the joints and fracture mode changed from ductile to brittle subsequent to FSW.

5. ALUMINIUM OXIDE REINFORCED AMC

Park et al. [19] investigated the high cycle fatigue behavior of the prepared 6061 Al-Mg-Si alloy reinforced Al_2O_3 composite with different volume fraction of reinforced. The experimental analysis illustrated that the fatigue behavior of the reinforced composites showed better results over the unreinforced alloy. Altinkok and Koker [20] evaluated bending strength and hardening behavior of the prepared Al_2O_3/SiC particulate reinforced AMCs and selected the fabrication technique as stir casting process. From the experimental results where mechanical forces were applied on the composite samples that the large particles consisted lower bending and hardness resistance whereas decreasing particle size showed higher bending and hardness resistance. Owolabi et al. [21] investigated the role of Al_2O_3 particulate reinforcement on the process of adiabatic heating to strain localization in Aluminum 6061 T6 alloy under high velocity. As the volume fraction of reinforcement increasing strength and stiffness of the composite were also enhanced. However it initiated the localized strain and forming adiabatic shear bands at high strain rate. Kannan and Kishawy [22] investigated the effects of cutting process parameters and properties of the reinforcement on the micro hardness of Al_2O_3 particulate reinforced AMC. They evaluated the variations of the micro hardness on the machined surface and proposed that near the machine surface region the micro hardness was higher and also low volume fraction and coarse particles had been higher micro hardness variations. Rupinder et al. [27] investigated tribological behaviour of dual particle size (DPS) and triple particle size (TPS) of Al_2O_3 reinforced aluminium matrix composites (AMCs) prepared by stir casting in vacuum mould. They established that DPS based AMC exhibited better wear resistance properties compared to TPS based AMC.

6. TITANIUM CARBIDE REINFORCED AMC

Gopalakrishnan and Murugan [23] investigated the characterization of the AA 6061 matrix titanium carbide particulate reinforced composite manufactured by the stir casting method. They established that the prepared composites were defect free and the selected method was the most economic and effective. As the increasing of the TiC in the composites, the specific strength was improved as well as maintaining the percentage of elongation. But the wear rate increased marginally with increased TiC addition. Michael Rajan et al. [24] fabricated aluminum alloy AA7075 reinforced with TiB_2 particles by the in situ process. They investigated the microstructure and the mechanical properties of the prepared composites and found that as the reinforcement increased the mechanical properties were distinctly improved. Also the microstructure of the composite showed defect free and no other intermetallic compounds form in the interface. Thangarasu et al. [25] investigated the characterization of the AA6082/TiC composites. Stir casting route was selected for prepared the composite samples. They found that the micro hardness of the composite increased upto 156 HV from 97 HV due to the addition of the TiC as well as the tensile strength increased from 223 to 265 MPa. However, the wear resistance capacity also improved as the increasing of TiC particles in the composites.

7. ZIRCON REINFORCED AMC

Kaur and Pandey [26] fabricated the zircon sand reinforced Al–Si alloy composite by using spray deposition technique. On the basis of the optical and SEM study they confirmed that there was a good bonding between the Zircon sand particles and the matrix alloy. The hardness of the composites increased as the addition of the Zircon sand particles in LM13 alloy. Also the process carried dendritic growth of α-Al grains in spray formed composite. Sucitharan et al. [28] investigated the wear behavior of the Al(6063)/Zircon Sand($ZrSiO_4$) composite prepared by stir casting method. They employed Pin on disk method for testing the wear behavior of the prepared composite samples with variation of wt. fraction. They proposed on the basis of the testing results that wear resistance capacity had been increased as the percentage of Zircon Sand increased in the composite. Ejiofor et al. [29] investigated tribological and tensile properties of the Zircon-particle-dispersed Al−13.5Si−2.5Mg composite. The X-ray study revealed that the interface reaction of the composite contained Mg, Ce, Cu, and Nb compounds. However they evaluated that the tensile failure of the composite carried as a ductile mode of fracture and recognized that the optimal performance of the composite achieved when the Mg content found in between 2.5 and 3.5 wt. % at $0.15V_f$ zircon. Rino et al.[30] investigated the mechanical properties of the Al6063 alloy/Zircon sand(ZrSiO4)/Alumina(Al2O3) particle composites with different wt fraction as (0+8)%, (2+6)%, (4+4)%, (6+2)%, (8+0)% were synthesized by the stir casting method. They established from the experimental results that the hybrid composites had better mechanical properties than single reinforced composites. However, (4+4) wt% combination would be provided the optimum wt. fraction of the hybrid composite in terms of microstructure and mechanical properties.

8. CONCLUSION

To summarize, the experimental data discussed in this review influence of the reinforcement on the microstructure, mechanical property and machinability of the AMCs and scrutinizing the effective and economic fabrication processes of AMCs. In this rapidly growing filed, the key experimentally documented trends and experiment based conclusions are briefly as follows:

(a) Compared to unreinforced Aluminium alloy, Aluminium MMCs have higher strength-to-density ratios, higher stiffness-to-density ratios better fatigue resistance, better elevated temperature properties and lower coefficients of thermal expansion.

(b) By using inexpensive reinforcement such as fly ash reduces the cost of fabrication.

(c) Addition of fly ash in Al alloy matrix increases the wear resistance and hardness of the composites whereas decreases the corrosion resistance capacity and ductility of the composites.

(d) Compocasting is the effective and economic process over other liquid state processes in terms of fabrication of Aluminium MMCs.

(e) SiC reinforced Aluminium based MMCs have higher wear resistance than Al_2O_3 reinforced AMCs.

(f) Hybrid AMCs composites have better mechanical properties than single reinforced AMCs.

(g) Al MMCs are difficult to machining in traditional machine due to the abrasive nature of the reinforcements.

(h) WEDM and EDM machine are more effective and economic to machining of AMCs compared to the other unconventional machining process.

REFERENCES

[1] Anilkumar H.C.,Hebbar H.S., Ravishankar K.S.Mechanical Properties of Fly Ash Reinforced Aluminium Allo (Al6061) Composites. International Journal of Mechanical and Materials Engineering (IJMME), Vol.6 (2011), No.1, 41-45.

[2] Mahendra K.V., Radhakrishna K. Fabrication of Al–4.5% Cu alloy with fly ash metal matrix composites and its characterization. Materials Science-Poland, Vol. 25, No. 1, 2007

[3] Sudarshan M.K., Surappa. Synthesis of fly ash particle reinforced A356 Al composites and their characterization. Materials Science and Engineering A 480 (2008) 117–124.

[4] David Raja Selvam ,Robinson Smart D.S., Dinaharan I. Microstructure and some mechanical properties of fly ash particulate reinforced AA6061 aluminum alloy composites prepared by compocastng. Materials and Design 49 (2013) 28–34.

[5] Narasimha Murthy I., Venkata Rao D. and Babu Rao J. Microstructure and mechanical properties of aluminum–fly ash nano composites made by ultrasonic method. Materials and Design 35 (2012) 55–65.

[6] Udaya Prakash J., Moorthy T.V., Milton Peter J., Experimental Investigations on Machinability of Aluminium Alloy (A413)/Flyash/B_4C Hybrid Composites Using Wire EDM, International Conference on Design and Manufacturing 2013, 1344-1355.

[7] Tamer Ozben, Erol Kilickap and Orhan Cakir // Materials processing technology 198 (2008) 220-225.

[8] S. Tzamtzis, N.S. Barekar, N. Hari Babu, J. Patel, B.K.Dhindaw and Z. Fan // *Composites: Part A* 40 (2009) 144.

[9] Quan Yanming and Zhou Zehua //*Materials processing technology* 100 (2000) 194.

[10] Sujan D., Z. Oo, Rahman M.E., Maleque M.A. and C.K. Tan // Engineering and Applied Sciences **6** (2012) 288.

[11] Shisheng Li, YishiSu, Qiubao Ouyang, Di Zhang, In-situ carbon nanotube-covered silicon carbide particle reinforced aluminum matrix composites fabricated by powder metallurgy, State Key Laboratory of Metal Matrix Composites, Shanghai Jiao Tong University, Shanghai 200240, PR China.

[12] Adem Onat, Mechanical and dry sliding wear properties of silicon carbide particulate reinforced aluminium copper alloy matrix composites produced by direct squeeze casting method. Sakarya University, Vocational School of Sakarya, 54100 Sakarya, Turkey, Journal of Alloys and Compounds 489 (2010) 119–124.

[13] Rana R. S., Rajesh Purohit and Das S., Tribological behaviour of AA 5083/Micron and Nano SiC composites fabricated by ultrasonic assisted stir casting process, International Journal of Scientific and Research Publications, Volume 3, Issue 9, September 2013 ISSN 2250-3153.

[14] Narayana Murty S.V.S., Nageswara Rao B., Kashyap B.P.// Composites science and technology 63 (2003) 119.

[15] Onoroa J.,Salvador M.D.,Cambronero L.E.G, High-temperature mechanical properties of aluminium alloys reinforced with boron carbide particles. Materials Science and Engineering A 499 (2009) 421–426.

[16] Cun-Zhu Nie, Jia-Jun Gu, Jun-Liang Liu, Di Zhang, Production of Boron Carbide Reinforced 2024 Aluminum Matrix Composites by Mechanical Alloying, Materials Transactions, Vol. 48, No. 5 (2007) pp. 990 to 995.

[17] Riaz Ahamed A., Asokan P., Aravindan S., EDM of hybrid Al–SiCp–B4Cp and Al–SiCp–Glassp MMCs. Int J Adv Manuf Technol (2009) 44:520–528.

[18]Kalaiselvan K.,Dinaharan.I., Murugan N., Characterization of friction stir welded boron carbide particulate reinforced AA6061 aluminum alloy stir cast composite, Materials and Design 55 (2014) 176–182.

[19] B.G. Park, A.G. Crosky and A.K. Hellier// Composites: Part B 39 (2008)1257.

[20] Necat Altinkok, Rasit Koker, Neural network approach to prediction of bending strength and hardening behaviour of particulate reinforced (Al–Si–Mg)-aluminium matrix composites. Materials and Design 25 (2004) 595–602.

[21] Owolabi G.M., Odeshi A.G., M.N.K. Singh,. Bassim M.N, Dynamic shear band formation in Aluminum 6061-T6 and Aluminum 6061-T6/Al2O3 composites, Materials Science and Engineering A 457 (2007) 114–119.

[22] S. Kannan and H.A. Kishawy // International Journal of Machine Tools & Manufacture 46 (2006) 2017.

[23] S. Gopalakrishnan, N. Murugan,Production and wear characterisation of AA 6061 matrix titanium carbide particulate reinforced composite by enhanced stir casting method, Composites: Part B 43 (2012) 302–308.

[24] Michael Rajan, Ramabalan, Dinaharan, S.J. Vijay, Synthesis and characterization of in situ formed titanium diboride particulate reinforced AA7075 aluminum alloy cast composites, Materials and Design 44 (2013) 438–445.

[25] Arumugam Thangarasu, Ramaswamy Mohankumar, Nadarajan Murugan, Perumalsamy Thangapandi, Processing and characterization of AA6082/TiC composites by stir casting, Emerging Materials Research.

[26] Kamalpreet Kaur, O.P. Pandey, Microstructural characteristics of spray formed zircon sand reinforced LM13 composite, Journal of Alloys and Compounds 503 (2010) 410–415.

[27] Rupinder Singh, Sunpreet Singh, Kanwalpreet Sahni, Effect of Double and Triple Particle Size Al_2O_3 Reinforcement on Properties of Aluminium Matrix Composite Prepared by Vacuum Moulding. 5 th International & 26th All India Manufacturing Technology, Design and Research Conference (AIMTDR 2014).

[28] K.S.Sucitharan, P.SenthilKumar, D.Shivalingappa, J.Jenix Rino, Wear Behaviour of Al6063-Zircon Sand Metal Matrix Composite. IOSR Journal of Engineering (IOSRJEN), ISSN: 2250-3021, p-ISSN: 2278-8719 Vol. 3, Issue 2 (Feb. 2013), ||V3|| PP 24-28.

[29] J. U. Ejiofor and R. G. Reddy, Interfaces and properties of Al – Si alloy zircon particulate composites. Journal of Materials Research /Volume 13 /Issue 11/1998, pp 3093-3099.

[30] Jenix Rino J.,.Sivalingappa D, Halesh Koti, Daniel Jebin, Properties of Al6063 MMC Reinforced With Zircon Sand and Alumina, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684 Volume 5, Issue 5 (Mar. - Apr. 2013), PP 72-77.

[31] B.H. Yan, C.C. Wang, Machinability of SiC particle reinforced aluminum alloy composite material, Journal of Japan Institute Light Metals 43 (4) (1993) 187–192.

[32] Monaghan J.M., P. O'Reilly, The drilling of an Al/SiC metal–matrix composite, Journal of Materials Processing Technology 33 (4) (1992) 469–480.

[33] Meena K.L.M., Banwait A. , Jaswanti S.S., Parametric effects during non- conventional machining of PR-AL-SiC-MMC's by CNC wire cut EDM, Int. J. Eng. Innov.Technol.3(1)(2013)341–345.

[34] Muller F., Monaghan J., Non-conventional machining of particle reinforced metal matrix composite, International Journal of Machine tools and Manufacture 40 (9) (2000) 1351– 1366.

[35]Saini.V,ZahidA.K,Siddiquee,A.N.,Optimizationofwireelectricdis charge machining of composite material (Al6061/SiCp) using taguchi method,Int. J. Mech.Prod.Eng.2(1)(2013)2315–4489.

[36] Ho KH, Newman ST, Rahimifard S, Allen RD (2004) State of the art in wire electrical discharge machining (WEDM). Int J Mach Tools Manuf 44:1247–1259.

[37] Benedict GF (1987) Nontraditional manufacturing processes.Marcel Dekker, Newyork.

[38] Kumar PRS, Kumaran S, Srinivasa Rao T, Natarajan S. High temperature sliding wear behavior of press–extruded AA6061/fly ash composite. Mater Sci Eng A 2010;527:1501–9.

[39] Zahi S, Daud AR. Fly ash characterization and application in Al–based Mg alloy. Mater Des 2011;32:1337–46.

[40] Michael Rajan HB, Ramabalan S, Dinaharan I, Vijay SJ. Synthesis and characterization of in situ formed titanium diboride particulate reinforced AA7075 aluminum alloy cast composites. Mater Des 2013;44:438–45.

[41] Sahin Y. Preparation and some properties of SiC particle reinforced aluminum alloy composites. Mater Des 2003;24:671–9.

[42] Hashim J, Looney L, Hashmi MSJ. The enhancement of wettability of SiC particles in cast aluminum matrix composites. J Mater Process Technol 2001;119:329–35.

[43] Kerti I,Toptan F.Microstructural variations incast B4C-reinforced aluminum matrix composites (AMCs). Mater Lett 2008;62:12158.

[44] Ramesha CS,Keshavamurthy R,Channabasappa BH,Ahmed A.Microstructure and mechanical properties ofNi–Pcoated Si3N4 reinforced Al6061 composites. Mater Sci Eng A2009;502:99–106.

[45] J. Bienias, M. Walczak, B. Surowska, J. Sobczak, J. Optoelectronics Adv. Mater., 5, (2003), 55.

[46] Satishkumar D.,Kanthababu M.,Vajjiravelu V., Anburaj R., Thirumalai Sundarrajan N., Arul H.. Investigation of wire electrical discharge machining characteristics of Al6063/SiCp composites. Int J Adv Manuf Technol (2011) 56:975–986 DOI 10.1007/s00170-011-3242-5.