Evolution of Wear and Mechanical properties of Al-Cu alloy with Graphite and Fly ash Metal matrix composite

Annoji Rao. T.M[1] Dr. Mahendra K.V[2]
[1]Associate Professor, VVIT, Mechanical Engineering Dept,Bengaluru, India[1],
[2] Prof Mech. Engg, AMIES, Mechanical Engineering Dept, Bengaluru India[2]

ABSTRACT: Metal Matrix Composites are engineered materials, produced by the combination of two or more different materials to gain improved properties. In the current analysis, an Al–4.5% Cu alloy be used as the fly ash and graphite and matrix is reinforcement. Aluminum copper alloy matrix composite repels the much concentration due to their high thermal conductivity, lightness, moderate making temperature etc. graphite powders and fly ash are used since its low density and high strength. The composite was formed using stir casting approach. The fly ash was added in 3%, 6%, and 9 % by weight and graphite was added in 3%, 6%, and 9 % by weight to the molten metal. The composite was tested for mechanical properties,. Microstructure investigation was done using a scanning electron microscope to gain the distribution of graphite and fly ash in the aluminium matrix. The results found an increase in tensile strength and hardness with increasing the graphite and fly ash content.

Keywords — Wear, Metal matrix , Composites , Fly ash, Graphite.

I.INTRODUCTION

Traditional materials do not always provide the necessary properties under all service conditions. Metal matrix composites (MMCs) are advanced materials resulting from a combination of two or more materials (one of which is a metal and the other a non-metal) in which tailored properties are realized. MMCs have received considerable attention in recent years due to their high strength, stiffness, and low density. Data related to mechanical properties, wear, microstructure, etc., have been cited in the literature. It has been reported that particle size and wear parameters (sliding speed, material property, normal load) influence the wear of the material [1–3]. A variety of particles such as mica, Al_2O_3, graphite, and SiC have been used as reinforcement materials with aluminium alloys [4–8] as the matrices. The use of fly ash as a reinforcement material [9] results in improvement of mechanical properties of the composite. An extensive review on dry sliding wear characteristics of composites based on aluminium alloy was undertaken by Sannino et al. [10] and of their abrasive wear behaviour by Deuis [11]. Fly ash was separated into cenosphere and precipitator fly ash. The use of precipitator fly ash in aluminium decreases the density of composites and increases their wear resistance [12]. The composite was prepared by stir casting. Graphite and fly ash is used as reinforcement materials [13]. Aluminium matrix and graphite composites are advanced engineering materials with enhanced mechanical and physical properties [14]. The cooling rate of a casting is primarily a function of its section size, pouring temperature, and the material mould ability to absorb the heat. Increasing the cooling rate significantly influences the as-cast structure (refines both the graphite size and matrix structure) and therefore the mechanical properties and increase the cooling factor, which result in a higher hardness, decrease the strength and castings machinability can be severely impaired[15-16]. The many favourable mechanical, electrical, thermal, and biocompatible properties of graphite render it as an important material. Besides energy dissipation, many types of friction also cause the removal of material from either or both contacting surfaces; this phenomenon is referred to as "wear"[17-18].

Al6061-Graphite composite increasing amount of Graphite has resulted in increase in hardness. The dispersed Graphite and SiC in Al6061 alloy contributed in enhancing the tensile strength of the composites [19-21]. However, in case of The tensile strength is a function of volume fraction of reinforcement. As volume fraction of reinforcement increases tensile strength of composite increases. Graphite imparts excellent self lubricating property to the hybrid composite [20-24]. This results from the graphite and Fly ash particulate being able to adjust in the metal-free space (porosity) during quenching, resulting in a lower dislocation density. This reduces the amount of heterogeneous nucleation volume around the particulates and thus retards the rate of precipitation [25-26].In the present investigation, Al–4.5% Cu alloy with fly ash (as received from thermal power plant) as particulates were successfully fabricated using the stir casting method. Mechanical properties and dry sliding wear behaviour of the MMCs were investigated. Under these conditions, fragment of reinforcement can act as a third body that increases the aggressiveness. However, stir casting is the simplest and most economical method. It has been suggested to develop composite materials have the capacity to achieve low friction and wear at the contact interface without any external supply of lubrication during the sliding. The addition of reinforcement to aluminum matrix drastically alters mechanical, tribological and corrosion properties.[27-31].

II. EXPERIMENTAL PROCEDURE

Aluminium with 4.5% Cu was selected as the matrix material. The chemical composition of Al–4.5% Cu alloy is given in Table 1.Fly ash was used as the reinforcement and its composition is given in Table 2.The average particle size was found to be 10 μm. The density of fly ash was found to be 2.09 g/cm^3. Fig. 1 shows SEM micrographs of fly ash particulates.

Table 1. Chemical composition of Al–4.5% Cu alloy

Cu	Mg	Si	Fe	Mn	Ti	Zn	Al
4.5	1.00	0.60	0.65	0.10	0.10	0.20	Balance

Table 2. Chemical composition of fly ash in weight percentages

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Loss on ignition
30.40	58.41	8.44	2.75	1.43

Chemical composition of graphite is the purest form of carbon.The metal matrix composite was prepared by stir casting. The billets of Al–4.5% Cu alloy were taken in a graphite crucible and melted in an electric furnace .The temperature was slowly increased to 860 °C. The melt was degassed at 800 °C with a solid dry hexachloroethane (C_2Cl_6, 0.5 wt. %) degasser. The molten metal was stirred to create a vortex and the particulates were introduced. The degassed molten metal was kept below the stirrer and stirred near about 450 rpm. The preheated fly ash particles were poured into the melt. Small pieces of Mg chips (0.5 wt. %) were introduced to the molten metal to see to it that good wet ability of particles with the molten metal. The percentage of fly ash added in terms of 3, 6, and 9 wt. % and also the percentage of graphite added was 3, 6, and 9 wt. %. The stirred scattered molten metal was put into preheated S.G. iron moulds 25, 37,and 50 mm in diameter and 200 mmlength, cooled to room temperature in atmospheric pressure.

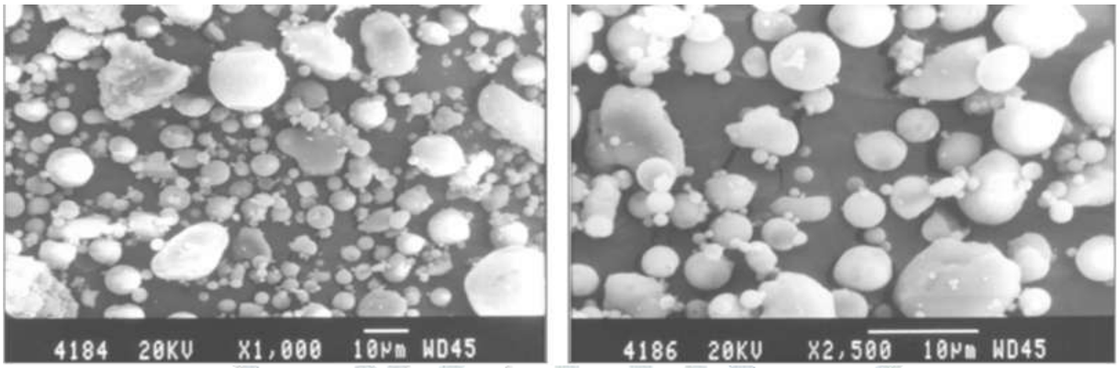


Fig. 1. SEM of fly ash particulates

Composites that were produced were subjected to solutionisation and age hardening (T6). The castings were heated to 525 °C and held for 17 hours, tempered in warm water, then reheated to 175 °C and kept for 18 hours. They were sectioned and test samples were prepared for various tests. Archimedes principle was used to measure the densities of the specimens. Brinell hardness tester determines their hardness. The load of 250 kg using a 5 mm steel ball indenter was used to measure the hardness. Scanning electron microscope is used to determine the microstructure of the MMC'S. at various locations across the specimen to examine the distribution of fly ash and graphite in the matrix. Tensile strengths is determined using a 20 kN computerized UTM with an electronic extensometer as per ASTM E-8 standards. Online plotting of load versus extension was done continuously through a data acquisition system (DAS).

III. RESULTS AND DISCUSSION

3.1. Tensile Properties

Table 3 shows the variation of tensile strength of the composites with the different weight fractions of fly ash and graphite particles. It can be noted that the tensile strength increased with an increase in the weight percentage of fly ash. It can also be noted that the tensile strength increases with an increase in the weight percentage of graphite. Increase in percentage of fly ash and graphite will also increase the tensile strength as it has been observed. Therefore the fly ash particles act as barriers to the dislocations when taking up the load applied (Basavarajappa et al., 2004; Seah et al. 1995). The hard fly ash particles obstruct the advancing dislocation front, thereby strengthening the matrix (Suresh et al., 2003). Its observed that the improvement in tensile strength of the composite is attributed to the fact that the filler fly ash and graphite posses higher strength and toughness. Table 3 shows the tensile test result of 25mm diameter rod,37mm diameter & 50mm diameter.

Table 3.Tensile Test Results

Sl no	Composition%	Tensile Strength(N/mm^2)		
		Dia25mm	Dia37mm	Dia50mm
1.	Flyash 3% Graphite 3%	100.49	119.33	105.88
2.	Flyash 3% Graphite 6%	109.68	145.10	189.88
3.	Flyash 3% Graphite 9%	119.4	149.33	200.52
4.	Flyash 6% Graphite 3%	125.33	180.99	95.94
5.	Flyash 6% Graphite 6%	149.92	183.4	128.33
6.	Flyash 6% Graphite 9%	152.52	206.97	154.96
7.	Flyash 9% Graphite 3%	161.67	171.57	143.46
8.	Flyash 9% Graphite 6%	171.57	181.98	201.25
9.	Flyash 9% Graphite 9%	181.98	260.30	201.28

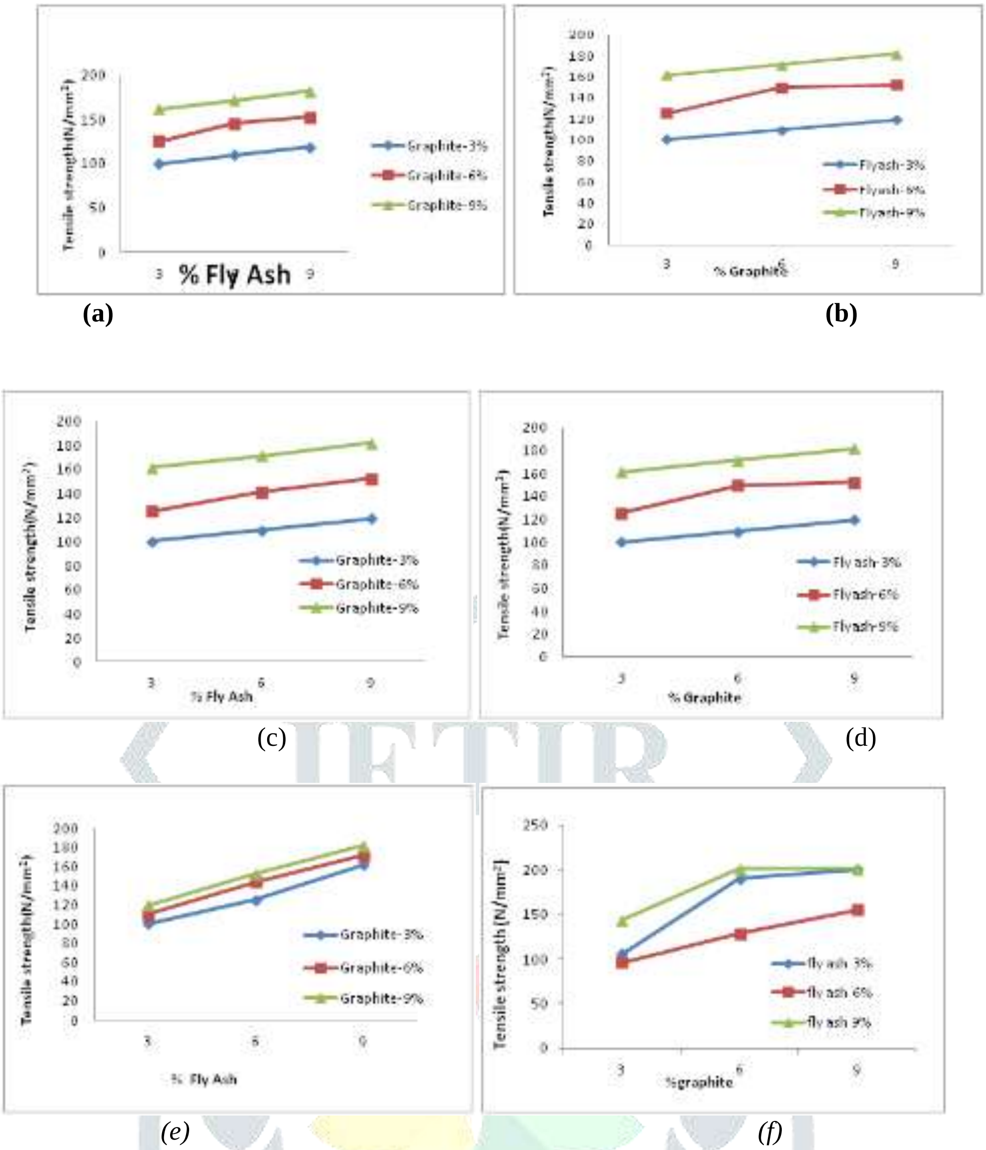


Fig. 2. Tensile properties of composites (a) Tensile_strength v/s % of fly ash in 25mm diameter(b) Tensile strength v/s % of graphite in 25mm_diameter(c) Tensile strength v/s % of fly ash in 37mm diameter(d) Tensile strength v/s % of graphite in 37mm diameter(e)Tensile strength v/s % of fly ash in 50 mm(f) Tensile Strength v/s % of graphite in 50mm diameter

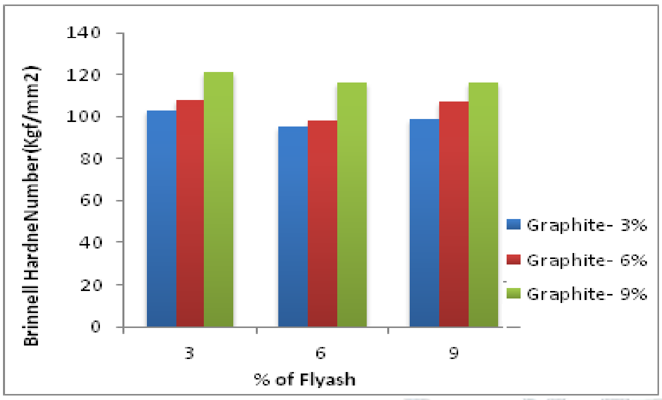
3.2. HARDNESS

From table.4, it can be noted that the hardness of the composite increased with the increase in weight fraction of the fly ash and graphite particles. Thus the hard fly ash particles help in increasing the hardness of the aluminium alloy (Al6061) matrix

Table 4 shows the hardness test result

Sl no	Composition %	Ball Dia'D' mm	Load 'F' (N)	Dia of Indentation 'd' (N)	Brinell Hardness Number (N/mm^2)
1	Flyash 3% Graphite 3%	5	250	2.10	578.79
2	Flyash 3% Graphite 6%	5	250	1.96	667.08
3	Flyash 3% Graphite 9%	5	250	1.74	774.99
4	Flyash 6% Graphite 3%	5	250	1.72	804.42
5	Flyash 6% Graphite 6%	5	250	1.80	931.95

6	Flyash 6% Graphite 9%	5	250	1.75	990.81
7	Flyash 9% Graphite 3%	5	250	1.68	1000.62
8	Flyash 9% Graphite 6%	5	250	1.55	1020.24
9	Flyash 9% Graphite 9%	5	250	1.48	1039.86



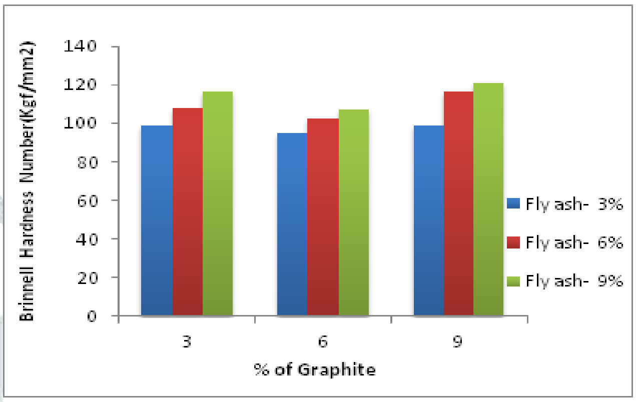
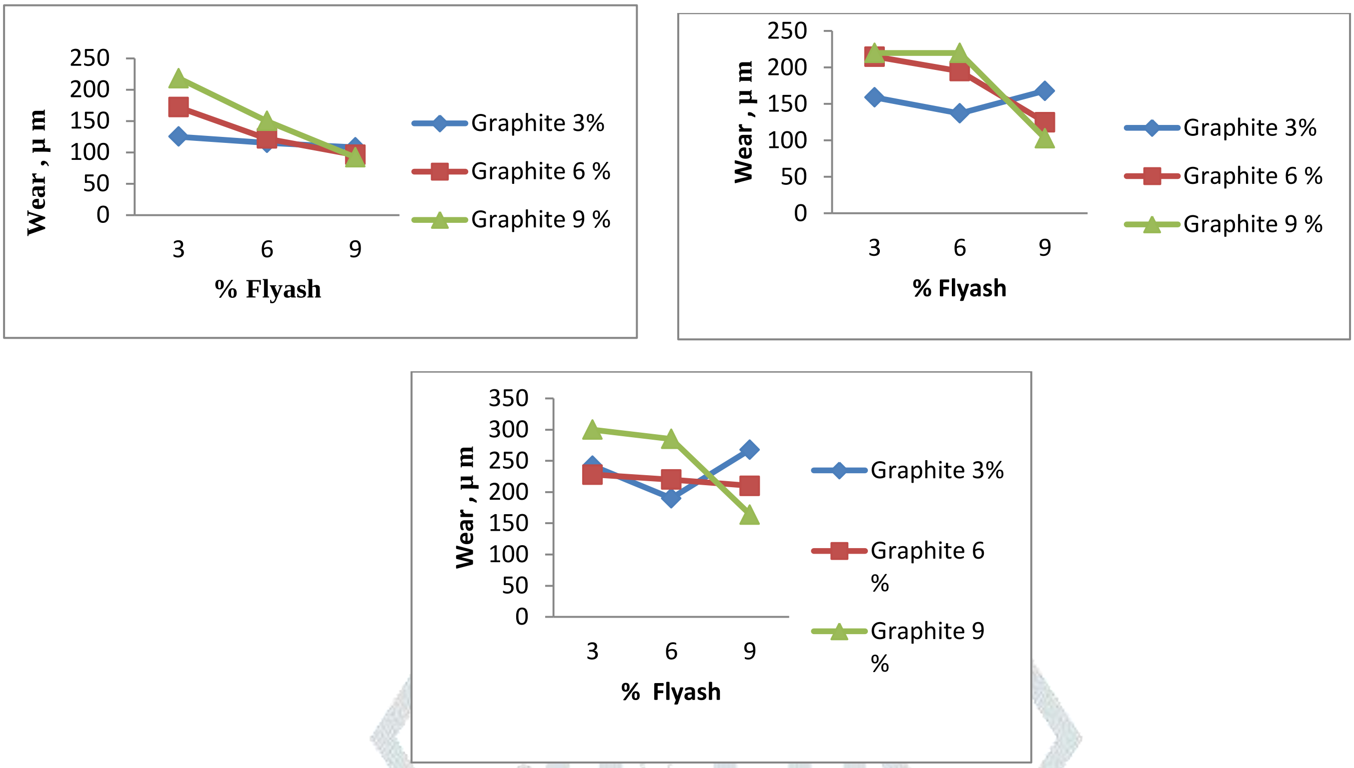


Fig. 4. Hardness properties of composites (a) Brinell Hardness Number v/s % of graphite Test results of 25mm diameter (b) Brinell Hardness Number v/s % of Fly ash Test results of 25mm diameter

3.3 Wear Properties

Table 4. Wear test results of Diameter 25 mm rod.

Sl no	Composition%	Wear in micrometer			
		4.9 N	9.8 N	14.7N	19.6 N
1	Flyash 3% Graphite 3%	125	159	242	263
2	Flyash 3% Graphite 6%	172	218	252	278
3	Flyash 3% Graphite 9%	202	225	264	296
4	Flyash 6% Graphite 3%	101	137	195	252
5	Flyash 6% Graphite 6%	122	202	224	258
6	Flyash 6% Graphite 9%	161	270	302	340
7	Flyash 9% Graphite 3%	108	168	268	310
8	Flyash 9% Graphite 6%	96	107	210	270
9	Flyash 9% Graphite 9%	83	92	164	214



(c)

Fig.3.Wear properties. (a) Wear v/s % Flyash with constant Graphite at 4.9 N load for the rod diameter of 25mm.(b) Wear v/s % Flyash with constant Graphite at 9.8 N load for the rod diameter of 25mm . (c) Wear v/s % Flyash with constant Graphite at 14.7 N load for the rod diameter of 25mm.

The graphs given above in Fig. 3 (a), (b), (c) and (d) are the graphs that represent the variation of reinforcement particles by weight percentage added to the base metal matrix of casted rods of diameter 25mm for varying loads of 4.9 N, 9.8 N, 14.7 N and 19.6 N. In the above graphs, the variation in the wear in the composites is observed by maintaining the weight percentage of graphite constant and varying the weight percentage of fly ash by 3%, 6% and 9%.

From the graphs given above it can be observed that:

1. The weight percentage of graphite at 3%, wear decreases with increase in the weight percentage of graphite at 6% but the wear increases with increase in weight percentage of graphite at 9%.
2. For the weight percentage of graphite at 6% and 9%, the wear decreases with increase in weight percentage of fly ash

IV CONCLUSION

1. MMC's containing up to 9% fly ash and 9% graphite particles were easily fabricated. A uniform distribution of fly ash and graphite was observed in the matrix.
2. As the percentage of graphite increases the tensile strength also increases.
3. As the percentage of fly ash increases the tensile strength also increases.
4. As the percentage of fly ash and graphite increases the tensile strength also increases.
5. As the percentage of graphite increases the hardness also increases up to 9% of graphite.
6. As the percentage fly ash increases the hardness also increases. up to 9% of fly ash.
7. Wear decreases with increasing percentage of fly ash.

REFERENCE

[1] EYRE T.S., Tribol. Int., (1976), 203.
[2] BHANSALI K.J., MEHRABIAN R., J. Metals, 34 (1982), 30.
[3] HOSKING F.M., PORTILLO F.F., WUNDERLIN R., MEHRABIAN R., J. Mater. Sci., (1982), 477.
[4] DEONATH S.K., BHAT R.T., ROHATGI P.K., J. Mater. Sci., (1980), 1241.
[5] MAJUMDAR B.C., YEGNESHWARAN A.H., ROHATGI P.K., Mater. Sci. Eng., 68 (1984), 885.
[6] POZA P., LLORCA J., Mater. Sci. Eng., A206 (1996), 183.
[7] PRADER P., DEGISCHER H.P., Mater. Sci. Technol., 16(2000), 893.
[8] IAN J.H., Metal Powder Rep., 10(1990), 689.
[9] ROHATGI P.K., GUO R.Q, J. Metall. Mater. Trans. B, 298 (1998), 519.
[10] SANNINO A.P., RACK H.J, Wear, 216 (1995), 1.
[11] DEUIS R.L., SUBRAMANIAN C., YELLUP J.M., Wear, 201 (1996), 132.
[12] GUO R.Q., ROHATGI P.K., Metal. Mater. Trans. B, 29B (1998), 51
[13] DIPTI KANTA DAS,PURNA CHANDRA MISHRA,SARANJIT SINGH,SWATI PATTNAIK,.,MATER SCI. ENG,17(2014),40712(AL1)
[14] DIPTI KANTA DAS,PURNA CHANDRA MISHRA,SARANJIT SINGH,RATISH THAKUR,MATER SCI.ENG,16(2014),40712(AL2)

[15] Wanlin GUO, Jun YIN, Hu QIU, Yufeng GUO, Hongrong WU, Minmin XUE,MATER SCI.,16(2014),64(GR31)
[16] Tuck Wah Ng, Chun Yat Lau, Esteban Bernados-Chamagne, Jefferson Zhe Liu, John Sheridan and Ne Tan,MATER SCI,14(2012),7(GR14)
[17] Marcin Go´rny and Edward Tyrała.,MATER SCI.22,(2013),305(GR7)
[18] N.A. WARNER,MATER SCI.(2008),10.(GR55)
[19] Basavaraju.S, Arasukumar.K,Dr.Chandrashekhar Bendigeri,Dr.C.K.Umesh, International Journal of Innovative Research in Science, Engineering and Technology vol1 (2012).
[20] Prakash C.H. and Pruthviraj R.D, Research Journal of Chemical Sciences, Vol. 1(6), 88-90, Sept. (2011)
[21] Mr. Prasanna, Mr. Devraj, Mr. Rakeshkumar, Mr. Mahadevappa, Asst Prof. Sharanabasappa R P, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume 11, Issue 3 Ver. VIII (May- Jun. 2014)
[22] Yanamandala Raghuram Chowdary, C.Yuvaraj, K. Prahlada Rao, B. Durgaprasad International Journal of Advanced Trends in Computer Science and Engineering, Vol.2, (2013)
[23] Satpal Kundu, Dr. B.K. Roy, Ashok Kr Mishra, International Journal of Scientific and Research Publications, Volume 3, Issue 8, August 2013
[24] Dunia Abdul Saheb, ARPN Journal of Engineering and Applied Sciences, VOL. 6, OCTOBER 2011.
[25] N. Nanda Kumar, P. Kanagaraj, International Journal Of Modern Engineering Research (IJMER)
[26] Yanamandala Raghuram Chowdary, C.Yuvaraj, K. Prahlada Rao, B. Durgaprasad, International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , (2013)
[27] S.Jagatheesh Kumar, G.Santhosh, D.Nirmalkumar, A.Saravanakumar, Dr.P.Sasikumar, Dr.S.Sivasankaran, Vol3,mar14
[28] MADEVA NAGARAL, V AURADI & RAVISHANKAR M K, vol 1,July 2013
[29] V. N. Gaitonde, S. R. Karnik, M. S. Jayaprakash,vol 11,july 2012
[30] Anandha Moorthy , Vinodh kumar , Kaviyarasu , Natarajan , Palani P,
[31] Dr. Rajanna S ,vol1, 2013