International Journal of Mechanical and Industrial Engineering

Volume 3 | Issue 1 Article 8

July 2013

EFFECT OF SOLUTIONISING TIME ON MECHANICAL PROPERTIES OF SQUEEZE CASTED AL 6082 – SICP COMPOSITE

R. GANESH
Department of Mechanical Engineering, R.M.K Engineering College, Chennai, India, rg.mech@rmkec.ac.in

M.S. AZHAKESH
Department of Mechanical Engineering, R.M.K Engineering College, Chennai, India, azhakesh.m.s@gmail.com

C. BALACHANDRAN
Department of Mechanical Engineering, R.M.K Engineering College, Chennai, India, C.BALACHANDRAN@gmail.com

K. CHANDRASEKARAN
Department of Mechanical Engineering, R.M.K Engineering College, Chennai, India, K.CHANDRASEKARAN@gmail.com

Recommended Citation
GANESH, R.; AZHAKESH, M.S.; BALACHANDRAN, C.; and CHANDRASEKARAN, K. (2013) "EFFECT OF SOLUTIONISING TIME ON MECHANICAL PROPERTIES OF SQUEEZE CASTED AL 6082 – SICP COMPOSITE," *International Journal of Mechanical and Industrial Engineering*: Vol. 3 : Iss. 1 , Article 8.
DOI: 10.47893/IJMIE.2013.1123
Available at: https://www.interscience.in/ijmie/vol3/iss1/8

EFFECT OF SOLUTIONISING TIME ON MECHANICAL PROPERTIES OF SQUEEZE CASTED AL 6082 – SIC_P COMPOSITE

R.GANESH[1], M.S.AZHAKESH[2], C.BALACHANDRAN[3] & K.CHANDRASEKARAN[4]

[1,2,3&4]Department of Mechanical Engineering, R.M.K Engineering College, Chennai, India
E-mail : rg.mech@rmkec.ac.in, azhakesh.m.s@gmail.com,

Abstract - Aluminum matrix composites refer to the class of light weight high performance aluminum centric material systems. The unique tailorability of the composite materials for the specific requirements makes these materials more popular in a variety of applications such as aerospace, automotive (pistons, cylinders, liners, bearings), and structural components, resulting in savings of material and energy. In this project, fabrication of Aluminum MMC by liquid metallurgy route (Squeeze Casting) is discussed in detail. The mechanical properties of 6082 aluminum alloy discontinuously – reinforced with fine particulates of SiC_p reinforcement and solutionising time during heat treatment of the composite on hardness, density and impact strength have been evaluated. The cardinal reasons behind the variation in the hardness and impact strength have been discussed.

***Keywords** - Metal matrix composite, squeeze casting, solutionising, hardness.*

I. INTRODUCTION

The research in material science has been directed towards the development of novel materials with unique combination of engineering properties for enhanced performance and optimized serviceability. To meet this, metal matrix composites (MMCs) have merged as an important class of engineering materials for the structural, wear, thermal, transportation and electrical applications. Among several metal matrix composites, aluminium matrix composites have wide applications, owing to their specific strength and resistance to corrosion. Futher, the properties related performance characteristics largely depend on processing route.

II. EXPERIMENTATION

The main objective of this project is to fabricate Aluminium Matrix Composites using squeeze casting process and also to study the effect of solutionising time on the mechanical properties of Al-SiCp composites.The workpiece was Aluminium 6082 alloy based metal matrix composite reinforced with SiCp in three different volume fractions (10%, 15% and 20%). The cast sample was solutionised and aged. Soutionising was carried out at 530 degree Celsius for a varied time period of 1hr, 2hrs, 3hrs, 4hrs and 5hrs in a muffle furnace. The pieces were then quenched in water to ensure stability of the precipitates formed. The quenched pieces were then artificially aged for 4 hrs at 170 degree Celsius [GulTosan et. al., 2004] in the same furnace. After the aging procedure they were allowed to cool at room temperature to avoid cracking of the aged samples.The following mechanical properties were evaluated analyzed for the various volume fractions of the composite

1. Vickers Hardness
2. Brinell Hardness
3. Density
4. Impact strength

III. RESULTS AND DISCUSSIONS

An important physical property of aluminium matrix composite is hardness- structural reinforcement of aluminium matrix composite is to enhance the basic hardness [Anand Ronald et. al., 2007] so that the composite can withstand normal wear modes encountered in practice. Mostly % volume fraction of reinforcement influences the hardness. In order to maintain hardness at desired level to avoid brittleness, one has to balance the volume fraction, illustrating the role of volume fraction of reinforcement on hardness related properties of metal matrix composites.

A. Brinell hardness – observation

The following values were observed for different volume fractions of the reinforcement, the aluminium MMC in the Brinell hardness test conducted using a 5mm steel ball with 250kgf load. The test was conducted before and after aging treatment.

1) Before aging: Typical values of hardness measured are listed in table I. It is seen that the hardness of the composite increases with increase in volume fraction of SiCp. This happens due to the dispersion of relatively harder SiC particles in the metal matrix. [Xue et. al., 2009] Further, the hardness value for a given volume fraction increases progressively upto the solutionising time of three hours. This happens due to the highly effective bonding of the reinforcement with the matrix. Prolonged exposure to high temperatures causes the composite to lose its hardness property, owing to possible grain growth in the matrix.

TABLE I. BHN (before aging)

Solutionising time	10% V_f	15% V_f	20% V_f
Hours	**BHN**	**BHN**	**BHN**
0	73	78	88
1	79	97	121
2	94	104	128
3	98	118	139
4	103	116	134
5	104	113	128

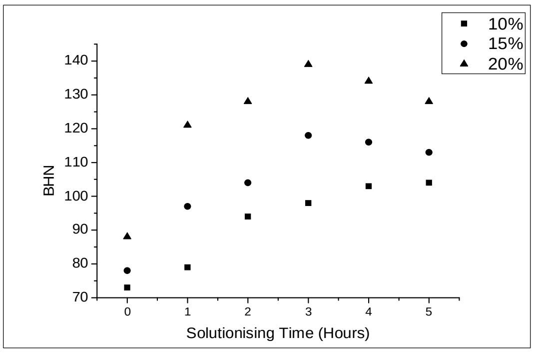

Fig. 1. Effect of solutionising time on BHN (before aging)

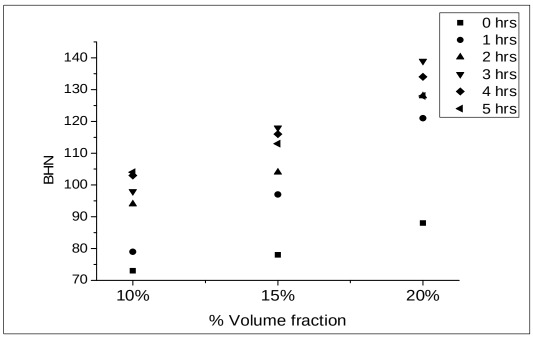

Fig. 2. Effect of volume fraction on BHN (before aging)

From the above illustration, it is seen that with increasing volume fraction, a visible increase in hardness is seen. Beyond a certain time of solutionising (2-3 hours), only a marginal change in hardness occurs. Typical influence of % volume fraction of reinforcement on hardness of aluminium matrix composite is shown in the figure 2. It is see that beyond 15%, there is an appreciable rise in hardness of the composite. Further compared to plain alloys, the composite after solutionising experiences higher hardness. It is also seen that after a certain period of solutionising the hardness limits to set in. Typical influence of solutionising on hardness of the composite can also be seen in the figure. It is seen that continuous exposing to solutionising (beyond 3 hours), there is a reduction in hardness. Continuous exposure can soften the basic aluminium matrix and consequent reduction in hardness.

2) After aging : After solutionising, artificial aging was carried out. [Tekman et. al.2003] This has resulted in higher hardness values for the given composite material. During the aging the solutionised material picks up hardness (settling of precipitates). Typical measured hardness values are tabulated in Table II. From the figures 3-4, it is seen that at higher volume fraction, there is a visible rise/increase in hardness of the composite. With aging time, especially at higher volume fraction of reinforcing SiC particle, a rise in hardness occurs, beyond 3hours of aging, the hardness changes only marginally. The grain structure refinement can also be considered as a reason for the observed change in hardness.

TABLE II. BHN (after aging)

Solutionising time	10% V_f	15% V_f	20% V_f
Hours	**BHN**	**BHN**	**BHN**
0	73	78	88
1	88	117	131
2	104	123	137
3	107	132	148
4	110	127	146
5	112	124	139

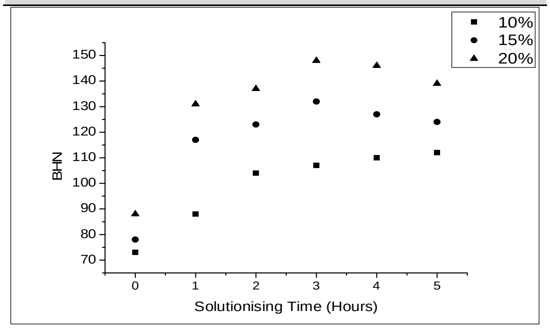

Fig.3. Effect of solutionising time on BHN (after aging)

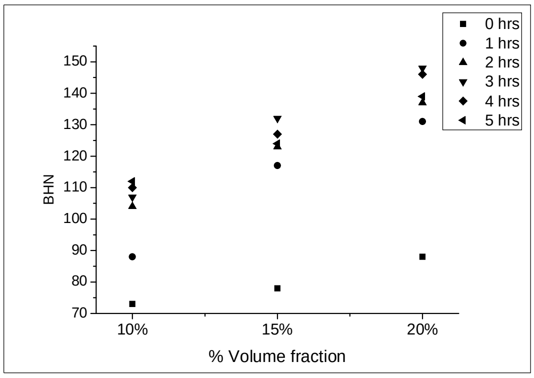

Fig. 4. Effect of volume fraction on BHN (after aging)

It can also be seen that with higher volume fractions, the reduction in hardness after three hours of solutionising is higher, due to the aggleromation of SiC particles in the composite. Referring to the table III, it is literally to observe that despite increase in hardness with volume fraction as solutionising, the % increase in hardness due to aging steadily drops down with solutionising time. This can be attributed to longer exposure to heating. Also there is a critical value of % reinforcement (Volume fraction) above which the % increase in hardness drops down.From figure 5, it is seen that % increase in hardness after aging increases for volume fraction 15% where as drops for other volume fractions. Appreciable rise in hardness can be seen for 15% volume fraction. With time of solutionising, reduction in % increase in hardness can be seen for 15% volume fraction and 10% volume fraction where as increases for 20% volume fraction.

TABLE III. % Increase in BHN after aging

Solutionising time (hours)	10% V_f (BHN)			15% V_f (BHN)			20% V_f (BHN)		
	Before aging	After aging	% increase in BHN	Before aging	After aging	% increase in BHN	Before aging	After aging	% increase in BHN
1	79	88	11	97	117	12	121	131	8
2	94	104	11	104	123	18	128	137	7
3	98	107	9.2	118	132	12	139	148	6.6
4	103	110	6.8	116	127	9.5	134	146	8
5	104	112	7.7	113	124	9.7	128	139	8.6

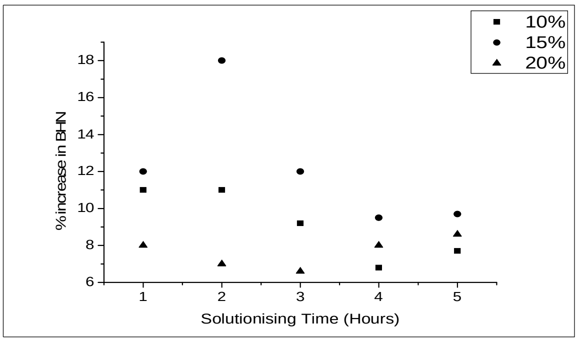

Fig. 5. Effect of solutionising time on % increase in BHN

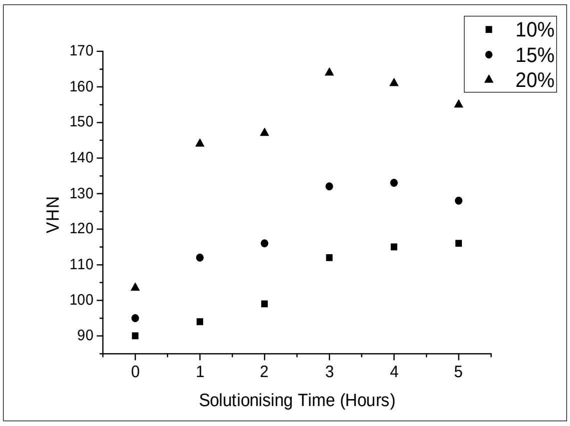

Fig. 6. Effect of solutionising time on VHN (before aging)

B. Vickers hardness

Vickers hardness measurement was carried out with indentation load of 10 kgf. The Vickers hardness test was carried out with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load of 10 kgf. The Vickers hardness test was conducted before and after aging.

1) Before aging: The values obtained with Vickers Hardness test were very much similar to that of the Brinell hardness and shown in table IV. The 20% volume fraction composite showed a sharp rise in the hardness value mostly due to the presence of higher SiC particles content, illustrated in the figures 6-7.

TABLE IV. VHN (before aging)

Solutionising time	10% V_f	15% V_f	20% V_f
Hours	VHN	VHN	VHN
0	90	95	103.5
1	94	112	144
2	99	116	147
3	112	132	164
4	115	133	161
5	116	128	155

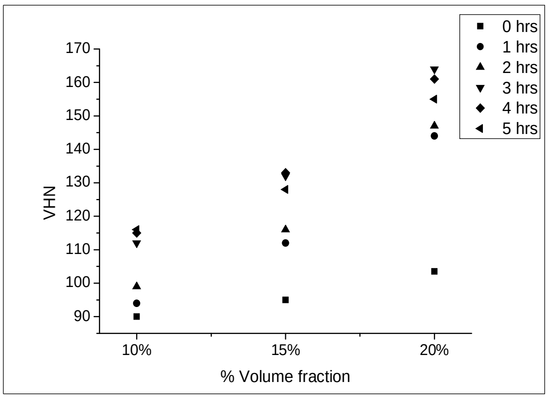

Fig.7. Effect of volume fraction on VHN (before aging)

2) After aging: After aging the hardness values of both 15% & 20% volume fractions tend to dip whereas, the 10% volume fraction composite maintained an increasing trend. This is due to the excessive SiC particles getting aggleromated at higher temperatures. Typical hardness values are listed in the tableV. From the figures 8-9, it was seen that at higher volume fraction of reinforcement, the composite material pick up considerable increase in hardness. Especially with aging, the composite at higher volume fraction of reinforcement exhibit higher hardness. With volume fraction, VPN increases. There is a visible rise in hardness after solutionising. However, beyond 3 hours, there is a marginal reduction in hardness. After aging the composite picks up hardness. % increase in hardness was tabulated in table VI and from figure 10, it is seen that % increase in hardness afteraging increases for volume fraction 15% where as drops for other volume fractions. Appreciable rise in hardness can be seen for 15% volume fraction.

TABLE V. VHN (after aging)

Solutionising time	10% V_f	15% V_f	20% V_f
Hours	VHN	VHN	VHN
0	90	95	103.5
1	103.5	133.5	154
2	116	136	164
3	120	154	180
4	125	146	177
5	127	141	167

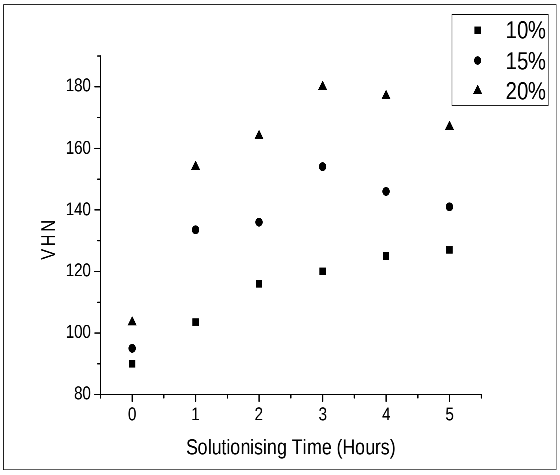

Fig.8. Effect of solutionising time on VHN (after aging)

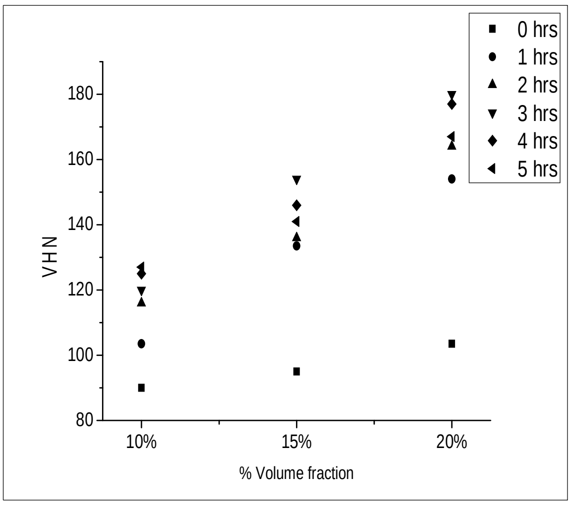

Fig. 9. Effect of volume fraction on VHN (after aging)

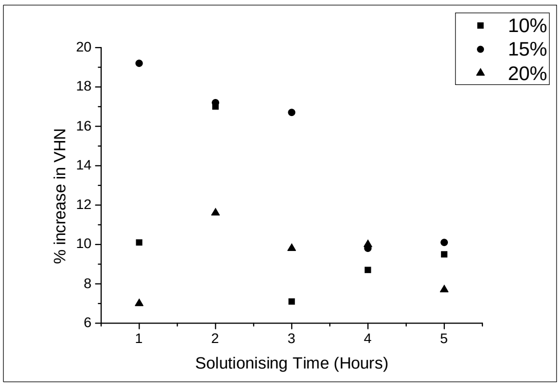

Fig. 10. Effect of solutionising time on % increase in BHN

C. Density

The density of the Al-SiC_p for the various volume fractions and different solutionising temperatures were calculated theoretically and experimentally [Fluery et. al., 2000] upto 10% volume fraction followed by a drop at higher volume fractions.

1) Theoretical Density: The density of the composite was theoretically calculated using the rule of mixtures

$$\rho_c = \rho_m (1-V_p) + \rho_p V_p$$

where, ρ_c = density of the composite in gm/cc.

ρ_m= density of the matrix in gm/cc.

ρ_p= density of the particulate reinforcement in gm/cc.

Substituting the density value of SiC, ρ_c= 3.21gm/cc and, the density of Al 6082, ρ_m=2.7gm/cc, the following values were obtained,

TABLE VII. Theoretical density

V_f	Density (g/cc)
10%	2.75
15%	2.78
20%	2.81

2) Experimental Density: The experimental density of the composite was calculated using the formulae

Density,ρ=(Mass/Volume) (gm/cc)

Substituting the values for mass and volume the density of the composite for the various volume fractions before and after the heat treatment was calculated and tabulated in tableVIII.

TABLE VIII. Experimental density

V_f	Density before heat treatment (g/cc)	Density after heat treatment (g/cc)
10%	2.38	2.39
15%	2.63	2.65
20%	2.74	2.75

TABLE VI. % Increase in VHN after aging

Solutionising time (hours)	10% V_f (VHN)			15% V_f (VHN)			20% V_f (VHN)		
	Before aging	**After aging**	**% increase in VHN**	**Before aging**	**After aging**	**% increase in VHN**	**Before aging**	**After aging**	**% increase in VHN**
1	94	103.5	101	112	133.5	192	144	154	7
2	99	116	17	116	136	172	147	164	11
3	112	120	7.1	132	154	167	164	180	9.8
4	115	125	8.7	133	146	9.8	161	177	10
5	116	127	9.5	128	141	10	155	167	7.7

.

Theoretical and actual density of 10% and 15% composites varied by a large margin. This shows that a high porosity content in these composites. This occurs during the casting process due to improper mixing of particulates with the metal. [Xu et. al., 2008]With higher volume fraction of reinforcement, the cast samples exhibit density varying marginally from the theoretical one. Aging has not influence the density.

D. Impact strength

The impact strength of the composites was obtained from the Charpy test.

1) Charpy Test: The composites of various volume fractions were shaped to the optimum sample size required for the Charpy test. The samples were then loaded and the values were obtained and tabulated in table IX for the various volume fractions of the composite.

Table IX. Impact strength

Solutionising time (hours)	10% V_f	15% V_f	20% V_f
	Impact strength (J)	Impact strength (J)	Impact strength (J)
0	9	11	12
1	11	12	16
2	19	14	19
3	23	27	22
4	33	37	44
5	30	29	34

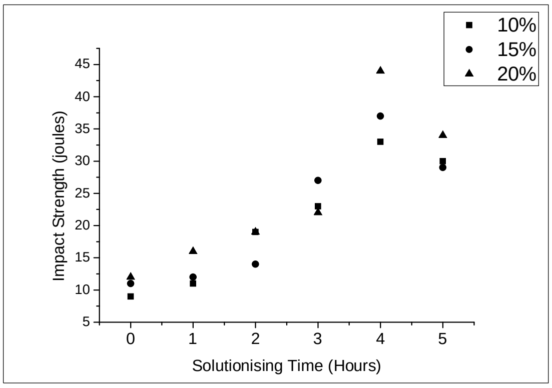

Fig.11. Effect of solutionising time on Impact strength

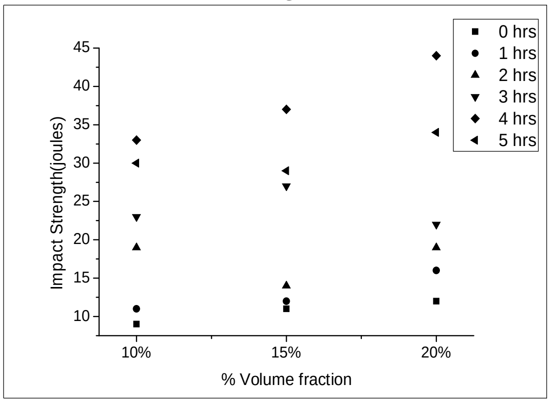

Fig.12. Effect of volume fraction on Impact strength

From the figures 11-12, it was found that there was mixed influence of parameters (% volume fraction and aging time) can be seen. Despite low hardness, composite with smaller volume fraction of reinforcement exhibit lower impact strength.With increasing volume fraction, a rise in impact strength could be seen. These are attributes to the variation of interface created with % volume fraction of the reinforcement.

The impact strength of the composites showed a tremendous increase for the samples which were solutionised for four hours and artificially aged for another four hours. The bonding between the matrix and the reinforcement is cited as the main reason for this increase. And also the presence of higher volume of reinforcement also increased the impact strength of the composites considerably.

IV. CONCLUSION

To match the needs of ever growing industries, newer materials with better properties are in great demand. The properties of Al-SiCp have been an area of research for many people. Since, very few attempts were made to study the influence of heat treatment on composites [Yusuf et. al.,], we made an attempt to investigate its effect on the mechanical properties of the composite. The properties of the composite were studied in detail in this research work. According to the project,

- The solutionising process increases the hardness considerably for any volume fraction of the composite.
- The best solutionising time for10%,15% and 20% volume fraction of Al-SiCp composite is three hours at530degree Celsius.
- Further increase in hardness can be witnessed when the solutionised composite is artificially aged for four hours at 170 degree Celsius.
- When solutionising time was increased beyond three hours the hardness value decreased depicting bond failure within the composite.
- The impact strength of the composite also increased with increase in volume fractions of the reinforcement.
- Maximum impact strength for the Al-SiCp was obtained when work, it can be concluded that, the samples were solutionised for four hours and artificially aged for four hours.
- The hardness of the composite increases with increase in the volume fraction of the reinforcement. Here, increase in volume fraction of SiCp increased the hardness of the composite.
- When solutionising was done for more than four hours the impact strength of the composite reduced Solutionising and aging did not have any considerable effect on the density of the composite.

REFERENCES

[1] B. Anand Ronald, L. Vijayaraghavan and R. Krishnamurthy, 'Materials Forum' Volume 31, 2007.

[2] GulTosun, Mehtap Morotuglu, 'Drilling of Al-SiCmetal matrix composite part 1 microstructure'– Composites science and technology 64 (2004) pp 299-308.

[3] C. Tekmen, I.Ozdemir, U.Cocen, K.Onel 'The mechanical response of Al-Si-Mg Sic composite-influence of porosity' – Material science and Engineering A360 (2003) pp 365-371.

[4] E.Fluery, S.M.Lee, W.T.Kim, 'Evaluation of the mechanical properties of conventionally cast Al matrix composites reinforced by quasicrystalline Al-Fe-Cu particles using continuous ball indentation technique' – Metals and materials Vol6, No 5 (2000) pp 415-422.

[5] Jia Li, Quiang Liu, Rui Xia Shi, 'Preparation and mechanical properties of Fe3Al(Ti)/TiC composites' – Journal of materials processing and technology 208 (2008) pp 105-110.

[6] A.K.Srivastava, C.L.Xu, B.Q.Wei, 'Microstructural features and mechanical properties of carbon nanotubes reinforced aluminium matrix composites'– Indian journal of engineering and material sciences vol 15 (2008) pp 247-255.

[7] Mehmet Gawhali, BurackDikisi, 'Corrosion susceptibilities of Al- Cu/TiC MMCs fabricated by conventional hot pressing' - Indian journal of engineering and material sciences vol 14 (2007) pp303-308.

[8] MaoquanXue 'High temperature oxidation and wear behavior of powder metallurgically developed Ni- Cr-W-Al-Ti-MoS2 composite' - Indian journal of engineering and material sciences vol 16 (2009) pp 111-115.

[9] K.Mahadevan, K.Raghukandan, B.C.Pai, U.T.S Pillai, 'Experimental investigation on the influence of reinforcement and precipitation hardening parameters of AA 6061 – SiCp composites' - Indian journal of engineering and material sciences vol 14 (2007) pp 277-281.

[10] Yusuf Ozcatalbas 'Investigation of the machinability behaviour of Al4C3 reinforced Al based composite produced by mechanical alloying technique - Composites science and technology 63 (2003)pp53-61.

◈◈◈