

# Design of Components of 4 Stroke Engine using Hybrid Metal Matrix



V Amit M Naidu, S.D. Shelare, S.M. Awatade

**Abstract:** In the present study of Aluminum Metal Matrix Composites (AMMCs), specifically speaking, in our case Al-SiC-graphite have been discussed on the basis of literature review, comprising of similar characteristics of base aluminum alloy but not completely identical. Aluminum metal matrix composites have different properties when compared with Cast Iron and Aluminum. This difference in properties gives us a chance to design components which may give better results than the conventional ones. In a new approach, we are trying to develop new components for 4 Stroke Petrol Engine namely piston & connecting rod, which would have better Tensile Strength, Young's Modulus & Low Thermal Conductivity as compared to the pure Aluminum. Paper Setup must be in A4 size with Margin: Top 0.7", Bottom 0.7", Left 0.65", 0.65", Gutter 0", and Gutter Position Top. Paper must be in two Columns after Authors Name with Width 8.27", height 11.69" Spacing 0.2". Whole paper must be with: Font Name Times New Roman, Font Size 10, Line Spacing 1.05 EXCEPT Abstract, Keywords (Index Term), Paper Title, References, Author Profile (in the last page of the paper, maximum 400 words), All Headings, and Manuscript Details (First Page, Bottom, left side). Paper Title must be in Font Size 24, Bold, with Single Line Spacing. Authors Name must be in Font Size 11, Bold, Before Spacing 0, After Spacing 16, with Single Line Spacing. Please do not write Author e-mail or author address in the place of Authors name. Authors e-mail, and their Address details must be in the Manuscript details. Abstract and Keywords (Index Term) must be in Font Size 9, Bold, Italic with Single Line Spacing. All MAIN HEADING must be in Upper Case, Centre, and Roman Numbering (I, II, III...etc), Before Spacing 12, After Spacing 6, with single line spacing. All Sub Heading must be in Title Case, Left 0.25 cm, Italic, and Alphabet Numbering (A, B, C...etc), Before Spacing 6, After Spacing 4, with Single Line Spacing. Manuscript Details must be in Font Size 8, in the Bottom, First Page, and Left Side with Single Line Spacing. References must be in Font Size 8, Hanging 0.25 with single line spacing. Author Profile must be in Font Size 8, with single line spacing. For more details, please download TEMPLATE HELP FILE from the website.

**Keywords:** Al-SiC-Graphite Specimen, Melting Metallurgy Metal matrix.

## I. INTRODUCTION

What we have learned from our past is that due to our need the solid materials are being replaced by composite materials so as to fulfill our need for obtaining a light weight, elite, nature friendly and corrosion resistance materials [2].

Revised Manuscript Received on August 30, 2020.

\* Correspondence Author

**V Amit M Naidu**, Student, Department of Mechanical Engineering, Priyadarshini College of Engineering, Nagpur, Maharashtra, India.

**Prof. S.D. Shelare**, Assistant Professor, Department of Mechanical Engineering, Priyadarshini College of Engineering, Nagpur, Maharashtra, India.

**Prof. S.M. Awatade**, Assistant Professor, Department of Mechanical Engineering, Priyadarshini College of Engineering, Nagpur, Maharashtra, India.

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an [open access](#) article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

The production and regular improvisation of a variety of Aluminum based composition and use of hybrid metal matrix has been an area of influence in the field of material sciences and engineering for as long as three decades [3-5]. This has been only possible because composites made out of Aluminum shows versatility which has been a success in the field of development of better performing components than the conventional ones for defence, marine, automobile, aerospace and far more industrial based application processes including facilities for sports and recreation [6-7]. Metal composite materials have discovered application in numerous zones of day by day life for a long while. Regularly it isn't understood that the application utilizes composite materials. Delivering of such materials is done from regular generation and handling of metals. Combination of metal, ceramic and nonmetal provides limitless variation [8]. AMC's i.e. Aluminum based metal matrix composite has so many attractive properties that it has gained enormous importance in the field of aerospace and automotive industries. The need for obtaining a material with such optimal density, abrasive resistant properties and specific stiffness has been fulfilled by the use of these AMC's. Many reports that has been published associates themselves with the development of microstructure and distribution of particles in the matrix along with mentioning their mechanical behavior. At present there are three methods to produce these reinforced composites namely sprayed deposition techniques, powder metallurgy, and stir casting [9-11]. The basis behind this methodology is to obtain a Hybrid Composites made up of specific metal matrices which are engineered by amalgamating different substances so that we get a final product consisting of mixture of advantages of those primary materials. By combining in such a method provides one with a number of possible ways for designing a material [12-14]. In a nut shell reinforcement should consist a hard material because it assists in improvement of such desirable properties such as tensile strength and hardness which plays an important role where there is interaction of surfaces in relative motion as in bearings or gears [15]. In this paper an attempt has been made for introduction of AMMCs for manufacturing components of an IC Engine and to achieve better performance characteristics in terms of properties such as Young's Modulus, Poisson's Ratio, Impact Strength, Thermal Conductivity etc., also to reduce the overall cost of production of components as compared to their life span.

## II. PROCESSING METHODOLOGY

Various procedures can be employed in creation of metal matrix composite materials. What makes a procedure appropriate is determination of use, application and the necessary properties needed in that final product.



## Design of Components of 4 Stroke Engine using Hybrid Metal Matrix

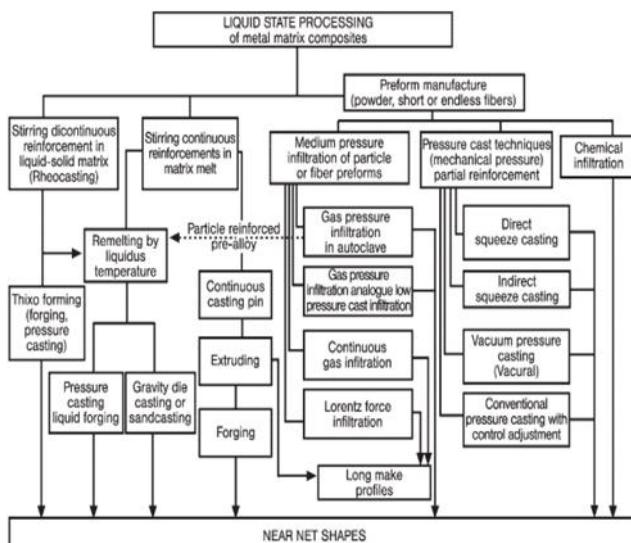
The manufacturing technique can be tweaked so as to acquire diverse profiles, even though similar techniques and segments are included in both.

The creation of an appropriate antecedent material, the handling of a unit under development or a partially completed product (profile) and the treatment given for finishing must be isolated. Following are engineering techniques which can be applied to obtain the final product:

- Melting metallurgical processes
- Using squeeze casting or pressure infiltration technique to infiltrate short fiber-, particle- or hybrid performs [16, 17–19]
- Infiltration of fiber- or particle preforms with the help of a reaction [20, 21]
- Processing of precursor material by stirring the particles in metallic melts, followed by sand casting, permanent mold casting or high pressure die casting [22, 23]
- Powder metallurgical processes
- Powder mixtures and composite powders being pressed and sintered and/or forged
- Metal-powder particle mixtures being extruded or forged [24, 25]
- Extrusion or forging of spraying compatible precursor materials [16, 26, 27]
- Hot iso-static pressing of powder mixtures and fiber clutches.
- Further processing of precursor material from the melting metallurgy by thixo-casting or -forming, extrusion [28], forging, cold massive forming or super plastic forming.
- Semi-manufactured products being joined and welded.
- Using techniques applied by machines for finishing [29]
- Deforming the combination of metal wires (group superconductors).

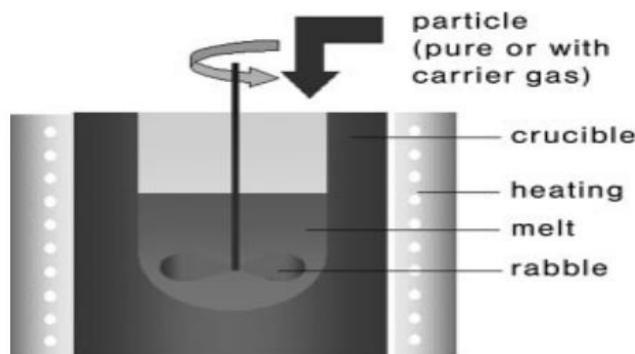
The 1st set of procedures is at present more suitable for generation of a composite of metal matrix of more prominent specialized significance than powder metallurgy. It is increasingly prudent and has the upside of having the capacity to utilize well demonstrated forms for creating of metal matrix composites. Figure 1.1 depicts the conceivable strategies for softening metallurgical creation. Preparation of composites can be done by utilizing any of the following three systems [19]:

- Melt stirring or Compo-casting.
- Gas pressure infiltration.
- Pressure casting or Squeeze casting.



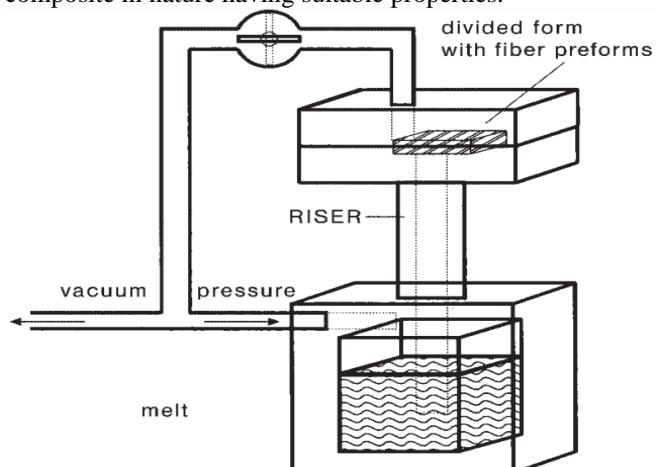
**Fig. 1.Melting metallurgy of MMCs**

The 1st method consists of using a stirrer to stir the particles in a melt of light alloy. Figure 1.2 depicts how the above mentioned procedure can be conducted schematically.



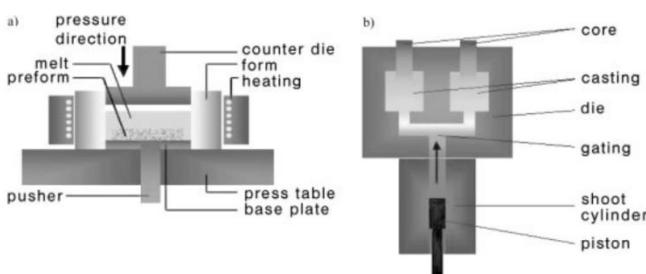
**Fig. 2.Procedure of melt stirring using schematic operation**

Melt penetrates into the perform in the presence of gas in gas pressure infiltration technique. A gas that is inactive as for the network is utilized. Reasonable pressure vessel is used for the penetration and liquefaction of the lattice. Gas pressure inversion can be performed by using any of the following two methods: The first one consists of a method in which the plunging of heated up preform is done inside the melt and after a connection of gas pressure is given from the outside, prompting penetration into the melt. Wettability of the performs facilitates the penetration pressure depending, on the volume level of fortification. The procedure is reversed in the second method of gas pressure penetration. Squeezing of liquid shower is done in perform with the help of connected gas pressure using a standpipe which immediately invades the bath (see Fig. 1.3). The positive side of applying this technique is, no further advancement of pores takes place when parts having higher density are used. Further more receptive materials can be utilized as this methodology consists of moderate response time for example with the compo-casting. Choosing and facilitation of material must be done wisely since reaction time is obviously longer in gas pressure penetration than in squeeze casting, so that they may deliver a desired material which is composite in nature having suitable properties.



**Fig. 3.Gas pressure Infiltration Technique**

The most widely used technique for casting of variations for composites of metal matrix is Pressure Casting or Squeeze casting. The melt cements and forms a fine-grained structure under exceptionally high pressure. Thermal treatment is possible for parts of delivery in squeeze casted ones as compared to with those that are die casted as they don't possess gas consideration. The difference in between the two casting methods can be easily spotted (Fig. 1.4). The pressure for the infiltration of pre-assembled performs is connected directly to the melt in the case of direct casting. This technique helps in improving the structure of tools considerably since the die is thereby part of the mould. Nonetheless, a drawback is noticed in immediate methodology that is the quantity of dissolve plays a crucial role for determining the unit's cast size which further depends on the factor that how precisely the melt volume is resolved, since gate is absent here. Again due to the fact that there are oxidizing items that are created amid measurements is another drawback. Interestingly, in indirect squeezing, squeezing of the melt in the structure is done by using a grid matrix, thereby residuals is deposited outside this gate. The large diameter of the gate provides a stream rate to the melt which is significantly less than die casting, resulting in a less violent gas admission and form filling to the dissolve and turbulences is maintained within a limit. Composite materials can be obtained by performing any of the two pressure casting processes since both help in the penetration of pre-fabricated molecule into the melt which under pressure gets cemented. Generally a two step process is used. First step consists of squeezing the melt in structure by applying less pressure and after that for cementing stage greater pressure is applied. Since infiltration is not quick any harm to the preform is averted. Pressure casting grants utilization of moderately receptive substances, since time of penetration and alongwith it the time of reaction, are generally short. The possibility of fabricating units which are intricate and partially reinforced are easily favourable in such conditions so as to fortify regions presented to a greater stress amid their service life.



**Fig. 4.Direct and Indirect Squeeze Casting**

### III. PREPARATION OF ALUMINUM SILICON GRAPHITE SPECIMEN

Mix Casting strategy is a technique for creating products, having a dissipated stage (terminated substances, small fibers) is dissolved in a fluid metal by technique of mechanical blending with assistance of stirrer. The fluid state composite material is thrown by lasting bite the dust throwing technique. In this Stir throwing procedure has been utilized to set up the work-piece tests of Al-Sic-Graphite cross breed metal grid Composite material and achieve the required properties of that composite material. The vortex blend throwing is best way to deal with make an exact blending of the silicon carbide and graphite material in the network, the

aluminum material was stacked in a cauldron and it was put into an obstruction heater at different temperature levels [30].



**Fig. 5.Furnace**

Silicon carbide and Graphite powder preheated before blending of aluminum metal mould, the four edged stirrer was planned so as to create the adequate homogenous molecule dissemination all through the grid material [31]. In the wake of getting the homogeneous blending of silicon carbide, graphite powder and aluminum composite liquid metal was filled into permanent die. In casting process die is loaded up with a greasing material for reducing sticking of the casting metal to the die. The vent gaps are provided with the casting for escaping hot gas from the mold. The casting was removed from the die; the casting will be excessively hot, so it must be cooled so as to decrease the oxidation process. The casting material is cooled by the water quenching process. This procedure contains the fast cooling of the casting material by treating with the water. The casting is dunked in to a water to reduce the warmth and to get a solid form of the composite specimen.



**Fig. 6.Specimen of Aluminum Silicon Graphite**

### IV. TESTING OF SPECIMEN

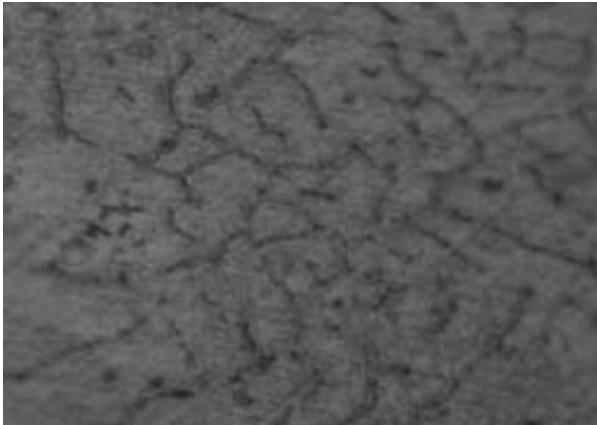
Following tests are performed:

- Tensile Test
- Brunel Hardness Test
- Impact Test
- Microstructure Analysis



## Design of Components of 4 Stroke Engine using Hybrid Metal Matrix

After comparison of the test results with conventional materials, the hardness of cross over metal lattice was enhanced to a greater extent. The surface of Al-Sic-Graphite is shown with help of optical microscope and getting the micro structure of graphite present in hybrid metal matrix.



**Fig. 7.Microstrecture of Specimen**

Following results were obtained:

**Table- I: Material parameters of Aluminum (Pure)**

Young's Modulus	7e+10 Pa
Poisson's Ratio	0.35
Density	2700 Kg/m <sup>3</sup>
Tensile strength	121.1 MPa
Percentage of elongation	10-15
BHN	60-65
Thermal Conductivity	237 W/m°C
Specific Heat	910 J/Kg°C

These Aluminum (Pure) Parameters are taken from the source [32].

**Table- II: Material parameters of Specimen**

Young's Modulus	7.4e+10 Pa
Poisson's Ratio	0.34
Impact Strength	87 J
Percentage of elongation	7.5
Density	2711.4 Kg/m <sup>3</sup>
Tensile Strength	193.38 MPa
BHN	68
Thermal Conductivity	180 W/m°C
Specific Heat	826 J/Kg°C

The martial structure for hybrid metal lattice is in presence of silicon carbide (50g) and graphite (30g). The hardness test report shows the hardness of the metal grid material increment by including the Si-C and graphite, by expanding the hardness of the composite specimen and reduction of deformation. The Brunel hardness number is better in the Al-Sic-Graphite test contrasted with the unadulterated aluminum. The impact strength has been increased by including the graphite in the metal grid. Quality gets degraded with increment of graphite in excess of 30 grams. In this metal framework level of extension diminishes with addition of graphite. Elasticity has been incremented by including the Si-C and graphite in composite material. The Young's modulus estimation of the hybrid metal matrix is higher contrasted with the aluminum. This exhibits that

Al-SiC-Graphite is better in every way when contrasted with the unadulterated Aluminum.

### V. EFFECT OF GRAPHITE CONTENT

Some influential parameters which play an important role during determining the wear resistance properties of composites consists of properties of the metal matrix composite, reinforcement's volume fraction as well as testing conditions applied. Graphite plays crucial character in reinforcing particles in the matrix of Aluminum composition. Such matrix which consists of graphite particles in Aluminum composites can produce such light weighted component which can be used in areas of contact wearing under different motions. Resistance to seizure is also improved in such cases [32, 33]. The influence of graphite content was examined by S. Mahdavi and F. Akhlaghion of slide wearing properties of Al6061/Gr hybrids along with Al6061/30SiC/Gr using a pin-on-disc wear test. The results showed that there was a reduction in porosity, friction coefficient and hardness in both the composite types when there is an increase in graphite content. Increase in porosity along with exhibition of high hardness character and lower coefficient of friction was exhibited by the hybrid composites with similar amount of graphite [34]. Although wearing increases if more graphite is added [35].

### VI. EFFECT OF PARTICLE SIZE OF SILICON CARBIDE

It has been found that a combination of particles and small fibers along with Hybrid metal matrix composites has been more efficient than those non hybrid metal matrix composites i.e. composites consisting of only one material as modulus and tensile strength of metal matrix composite is increased in the case of small fiber type, while wear resistance is improved in the case of particle type combination. Further these combined metal matrix composites are modified accordingly by using specific proportions of ceramic reinforcements. These combinations have also been taken into consideration as an alternative to the widely used whisker reinforced or high-cost small fibers products [36]. It is to be noted that composites which has Si-C particles of greater size has an upper hand as compared to those which has smaller sized particles in terms of their wear resistance properties [37].

### VII. CONCLUSIONS

- Conventional materials which has been used in automobile components are easily replaceable with hybrid composite with hardness factor and better performance for longer period of life.
- Hybrid composites reinforced with aluminum alloy matrix are easily casted. And again by adding of reinforcements of hybrid nature, various characteristics such as corrosive resistance, wear resistance, toughness and hardness can further be optimized.

- It has been found out that in applications where wearing is caused severely by moving parts such as in various components of automobile engines these metal matrix composites of Si-C contents of greater size are very much efficient.
- Although while comparing the rise in temperature for hybrid composite and binary composite, it has been found to be higher in hybrid ones but at the same time it is comparatively less as in the case of composites based on iron.
- While comparing the coefficient of friction and wear rates of hybrid composites, matrix alloy and individual composites, the hybrid ones has shown less wear rates as compared to the other two.

## REFERENCES

1. David Weiss Eck Industries, Inc., Design of Aluminum Metal Matrix Components for Casting, 2005-01-1689., SAE TECHNICAL PAPER SERIES.
2. Ashok Kr. Mishra, Rakesh Sheokand, Intl Journal of Sci & Research Publications, Vol 2, 10, Oct 2012.
3. Y.Wu, H.Liu and E.J.Lavernia, Scripta Metallurgica et Materialia,1993, 41- 61.
4. J.JenixRino,D.Chandramohan, (IJSR), India Online ISSN: 2319-7064.
5. D.J.Lloyd, Comp.Sci, and Tech., 35, 1989, pp.159-179.
6. M.K.Surappa and P.K.Rohatgi, Journal of Material Science. 16, 1981, pp 982-993.
7. P.S.Robi et.al, Mater.Chact., 27, 1991, pp. 11- 18.
8. Karl Ulrich Kainer, Metal Matrix Composites. Custom-made Materials for Automotive and Aerospace Engineering, ISBN: 3-527-31360-5.
9. S. K. Jo, W. J. Lee, Y. H. Park, I. M. Park, Tribol Lett (2012) 45:101–107.
10. S.Das and S.V.Prasad, Wear, 133, 1989, pp 173-187.
11. B.P.Krishnan, M.K.Surappa and P.K.Rohatgi, JMS., 16, 1981, 1209-1216.
12. S.Basavarajappa, G.Chandramohan, ISRS on Materials and Engineering December 20- 22, 2004.
13. Shyam Bahadur, Fundamentals of Friction and Wear.
14. S.Das et al., Mater.Trans., JIM, 32 (2), 1991, pp.189-194.
15. T.P.Murali, M.K.Surappa and P.K.Rohatgi, Metall. Trans., 13B, 1992, pp 485-494.
16. K. U. Kainer (Ed.), Metallische Verbundwerkstoffe, DGM Informationsgesellschaft, Oberursel (1994).
17. W.Henning, E. Köhler, Maschinenmarkt 1995, 101, 50–55.
18. S. Mielke, N. Seitz, Grosche, Int. Conf. on Metal Matrix Composites, The Institute of Metals, London (1987), pp. 4/1–4/3.
19. H. P. Degischer, Schmelzmetallurgische Herstellung von Metallmatrix-Verbundwerkstoffen, in Metallische Verbundwerkstoffe, K.U.Kainer (Ed.), DGM Informationsgesellschaft, Oberursel (1994), pp.139–168.
20. Lanxide Electronic Components, Lanxide Electronic Components, Inc., Newark USA (1995).
21. C. Fritze, Infiltration keramischer Faserformkörper mit Hilfe des Verfahrens des selbstgenerierenden Vakuums, Dissertation TU Clausthal (1997).
22. DURALCAN Composites for Gravity Castings, Duralcan USA, San Diego (1992).
23. DURALCAN Composites for High-Pressure Die Castings, Duralcan USA, San Diego (1992).
24. C. W. Brown, W.Harrigan, J. F. Dolowy, Proc. Verbundwerk 90, Demat, Frankfurt (1990), pp. 20.1–20.15.
25. Manufacturers of Discontinuously Reinforced Aluminum (DRA), DWA Composite Specialities, Inc., Chatsworth USA (1995).
26. G. Leatham, A. Ogilvy, L. Elias, Proc. Int. Conf. P/M in Aerospace, Defence and Demanding Applications, MPIF, Princeton, USA (1993), pp. 165–175.
27. Cospray Ltd. Banbury, U.K., 1992.
28. Keramal Aluminium-Verbundwerkstoffe, Aluminum Ranshofen Ges.m.b.H., Ranshofen, Österreich (1992).
29. F. Koopmann, Kontrolle Heft 1/2 (1996), pp. 40–44.
30. Nunna Durga Prasanth\*, Dr.B Venkataraman, Experimental investigation and analysis of piston by using hybrid metal matrix, IJESRT, ISSN: 2277-9655, 2015.
31. Er. Rachit Marwaha, Mr. Rahul Dev Gupta, Er. Krishan Kant Sharma "Determination & Experimental Investigation Of Weight Loss On Al/Sic/Gr - Metal Matrix Hybrid Composite By Taguchi Method" Volume 2, Issue 11, November 2013.
32. R. Ravi Raja Malarvannan and P. Vignesh "Experimental Investigation and Analysis of Piston by using Composite Materials" Vol 04, Article-K100; November 2013.
33. Joel Hemanth, Trans. AFS, 5, 1999, 769.
34. G. B. Veeresh Kumar, C. S. P. Rao, N. Selvaraj, JMMCE, Vol. 10, pp.59-91, 2011.
35. Harish K.Garg Intl Journal of Latest Research in Science and Technology Vol.1, Issue 1 :36-44,May- June(2012).
36. Haizhi Ye, ASM Int JMEPEG (2003) 12:288-297.
37. V.C.Uvaraja, International Journal of Engineering Technology Volume 2, 2012.

## AUTHORS PROFILE



**V Amit M Naidu**, student of Priyadarshini College of Engineering, Nagpur, Maharashtra, pursuing M.Tech(M.E.D.), interested area of research on material science. With a background of B.Tech(Mechanical) from Rashtrasant Tukadoji Maharaj Nagpur University.



**Prof. S.D. Shelare**, assistant professor at Priyadarshini College of Engineering, Nagpur, Maharashtra since 2015. Having a teaching experience of 9 years in Mechanical Engineering Department. Has published 24 papers so far.



**Prof. S.M. Awatade**, assistant professor at Priyadarshini College of Engineering, Nagpur, Maharashtra since 2013. Having teaching experience of 11 years in Mechanical Engineering Department. Has published 12 papers so far.

