Available online at https://asric.africa/engineering-sciences
ASRIC Journal of Engineering Sciences Vol.5(2)(2025) 61-67

Production and Characterization of Aluminium Matrix Composite Containing Silicon Carbide, Fly and Orange Peel Ash

Olayide R. Adetunji[1*], Korede S. Rasheed[1], Olanrewaju M. Adesusi[2] and Queeneth A. Kingsley-Omoyibo[2]

[1]Department of Mechanical Engineering, Federal University of Agriculture Abeokuta, Ogun State, Nigeria
[2]Department of Mechanical Engineering, Igbinedion University Okada, Edo State, Nigeria

*Correspondence Author; adetunjior@funaab.edu.ng

Received 25 April 2025; revised 09 May 2025; accepted 20 June 2025

Abstract

Metal matrix composites are sophisticated materials having reinforcement components to create materials with specific qualities such as stiffness, impact resistance that can be used in high-temperature situations.This research produced and characterized Aluminium matrix composite from Silicon Carbide, Fly and Orange peel ash (OPA).Casting was done from scrapped aluminium pot, Silicon carbide, Fly ash and prepared OPA. A cylindrical pattern was made using sand to create cavity for the casting. The melt composite was stirred for 3 mins. The sample was reheated for 15 mins before stirring it for another 2 mins. The melted composite was poured into already prepared mould and air cooled. Samples were prepared for tensile, compressive, hardness, and wear examinations to identify the mechanical properties of the composite produced. Scanning Electron Microscope (SEM) investigation was also performed on all samples to identify their microstructures. Aluminium matrix composite of 80% Al, 10% SiC and 10% Orange Ash produced the best result of 123 MPa, 23,056 N/m^{2,}, 42 BHv, 2.018 m^3/m tensile, compressive, hardness,wear rate, respectively. The SEM images revealed Aluminium background with particles of SiC and ash as intermetallic compounds.

Keywords: Aluminium Matric Composite, Production, Characterization,SiC, Ash

1. Introduction

Metal matrix composites are sophisticated materials that mix reinforcement components to create composite materials with specific qualities such as stiffness, impact resistance, and use in high-temperature situations. Nanocomposite is emerging as a high-strength advanced material for industrial applications, with the ability to meet modern needs in advanced engineering applications. The focus of this study is on gathering, assessing, and concluding a large body of work on the creation and characterization of metal matrix composites and nanocomposites, as well as identifying gaps in recent relevant research and advancements (Negi, 2019).

Composite materials are created by combining two or more materials with distinct qualities that do not disintegrate or blend together. The composite's various materials work together to give it its distinct features. Composite materials have been utilized by humans for thousands of years in a range of purposes. Early Egyptians and Mesopotamian settlers utilized a mixture of mud and straw to build robust and enduring structures around 1500 BC. The mixture of mud and straw in a brick gives great squeezing, ripping, and bending resistance. Ancient composite items, such as ceramics and boats, continued to be reinforced with straw (Ngo, 2020).

A laminar structure is the most common type of fibre-reinforced polymer, which is created thin layers of fibre and polymer are stacked and bonded until the appropriate thickness is obtained. A specific level of anisotropy in composite qualities can be produced by varying the fiber orientation among layers in laminate structures. Corrosion resistance, light weight, strength, lower material prices, greater productivity, design flexibility, and durability are just a few of the advantages of composites. As a result, composite materials are found in a variety of industries with many practical applications (Adetunji *et al.*, 2022).

The material to matrix formulation must be selected based on its properties and behavior, which includes reinforcing. Matrix alloy should be chosen after providing a positive reaction to chemical compatibility with its reinforcement and wettability to principal constituent in MMC processing behavior and reinforcement with a specific feature quality (Satyanarayana and Pillai, 2002; Lindroos and Talvitie, 1995).The Aluminum and its alloys have improved performance as a result of rising demand for lower energy use, air pollution, resource depletion, and economic growth.Fly ash is one of the wastes produced during coal burning. The components of fly ash produced vary greatly depending on the source and makeup of the coal being burned, but all fly ash contains significant levels of silica (silicon dioxide, SiO_2) (both amorphous and crystalline) and lime (calcium oxide, CaO) SiO_2, Al_2O_3, Fe_2O_3 are the primary elements of fly ash, with oxides of Mg, Ca, Na, K, and other minor ingredients. Orange Peel Ash is used to reinforce the Aluminum alloy due to the high impact it has on the mechanical properties of alloy.High wear resistance, good mechanical properties, such as high temperature strength and thermal shock resistance, are all characteristics of silicon carbide (SiC). It serves as an abrasive and, more recently, a semiconductor and gem-quality diamond imitator.

Materials' chemical composition and internal structure, such as grain size or crystal structure, determine their mechanical and physical properties. Some physical characteristics, like density and electrical conductivity, may be affected by metalworking operations or heat treatment. Nanoparticles and fibers are commonly added to nanocomposites to improve their mechanical strength, toughness, and electrical or thermal conductivity and also the extremely perishable and seasonal fruit peel wastes generated by the fruit juice processing sector are generally discarded, posing a dilemma for the processing companies and pollution monitoring authorities. Thus, the presence of biomaterials in fruit waste peels such as peel oil, pectin, and sugar can stimulate aerobic bacteria to decompose biodegradable organic matter into products such as carbon dioxide, nitrates, sulfates, and phosphates in water, potentially causing environmental problems, particularly water pollution.This research therefore was aimed to produce and characterize Aluminum matrix nano composite containing Silicon Carbide, Fly and Orange peel ash.

2. Materials and Methods

2.1 Materials Sourcing

The aluminum used was gotten from scrapped aluminum pot. Silicon carbide was purchased locally. Fly ash was gotten from the combustion of coal while the orange peels were collected locally after sun dried for 5 days. The orange peels were then smoked into ashes and the collected ashes were then sieved.

2.2 Sample Preparation

The aluminum alloy was measured according to the necessary amounts in a weighing scale and was then put inside the crucible. The measured quantity of each reinforcing particle (SiC, Fly and Orange Peel Ash) was distributed into molten aluminum. The furnace was switched on for 20 min, the composite was then stirred for 3 min. The sample was reheated for 15 min before another stirring for 2 min. The slag on the surface of the melted sample was removed. The melted composite was poured into already prepared mould and air cooled. Three different samples were produced varying the Silicon Carbide and the Ash contents.

2.3 Mechanical Property of the samples

The Tensometric materials testing machine ((BS240 using Tensometer M500 to 25KN) to determine both the tensile and compression strength of the produced samples. Hardness tester (Gunt Hamburg Hardness tester) was used to determine the hardness of the sample. Wear rate test was carried out on the samples using Universal Wear tester (WP300).

2.4 Characterisation using Scanning Electron Machine

The produced Aluminium composite samples were characterised using Scanning Electron Machine (SEM).

3.0 Results

3.1 The Produced Samples of Aluminium Composite

The samples produced after machining are shown in Fig.1.

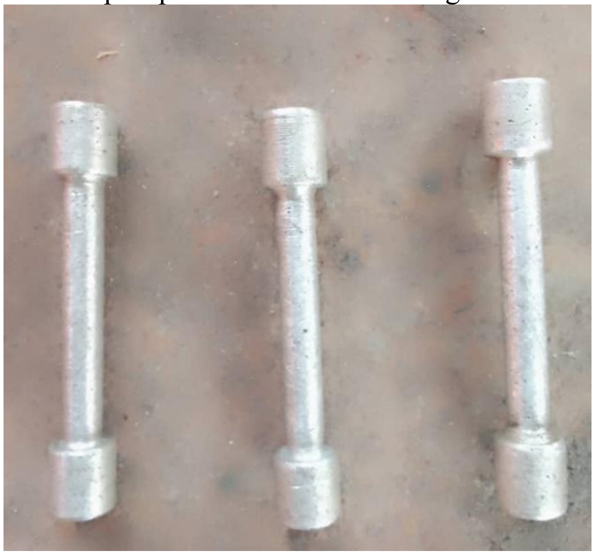

Fig.1 The machined Aluminium composite samples.

3.2 Result of Mechanical Property Investigation

The result of the tensile strength investigation is contained in Table 1, Compressive strength in Table 2, Brinel Hardness in Table 3 and Wear rate in Table 4. The tensile strength increases from 102 MPa to 123 MPa with increase in Silicon Carbide and Ash content.When the Silicon Carbide and ash content increased from 10% to 20% wt%, the composites' compressive strength begins to deteriorate from 24.689 kN/m^2 to 22.810 kN/m^2. The Brinel Hardness result followed the trend of that of Tensile strength. The wear rate was lowest in sample with 80% Al, 10% SiC and 10% Orange Peel Ash followed by sample with 90% Al, 5% SiC and 5% Fly Ash but it was highest in sample with 80%Al, 10 SiC and 10% Fly Ash.

Table 1: Result of Tensile Strength Investigation

Samples	Composition	Tensile Strength (MPa)
A	80%Al+10%SiC+10%FlyAsh	117
B	80%Al+10%SiC+10%Orange Peel Ash	123
C	90%Al+5%SiC+5%FlyAsh	102

Table 2: The result of compressive strength for the samples.

Samples	Composition	Compressive Strength (N/m^2)
A	80%Al+10%SiC+10%FlyAsh	22810
B	80%Al+10%SiC+10%Orange Peel Ash	23056
C	90%Al+5%SiC+5%FlyAsh	24689

Table 3: The result of Brinel Hardness for the samples

Samples	Composition	Brinel Hardness (HBW)
A	80%Al+10%SiC+10%FlyAsh	41.2
B	80%Al+10%SiC+10%Orange Peel Ash	42
C	90%Al+5%SiC+5%FlyAsh	38

Table 4: The result of Wear Rate for the samples.

Samples	Composition	Wear Rate (m^3/m)
A	80%Al+10%SiC+10%FlyAsh	5.932
B	80%Al+10%SiC+10%Orange Peel Ash	2.018
C	90%Al+5%SiC+5%FlyAsh	4.690

3.3 SEM Result

The SEM images revealed Aluminium background with particles of SiC and ash as intermetallic compounds. Figures 2 to 7 contained the SEM images of the samples.

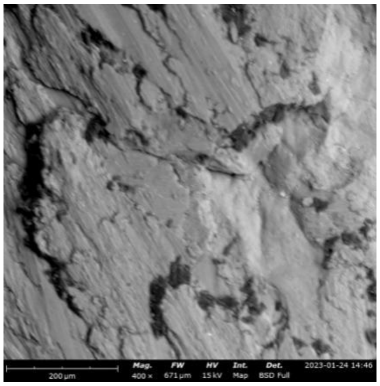

Fig.2 : Sample A (X410)

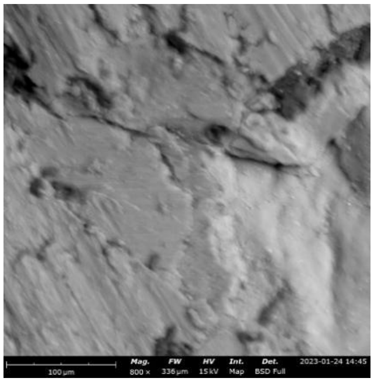

Fig. 3 : Sample A (X800)

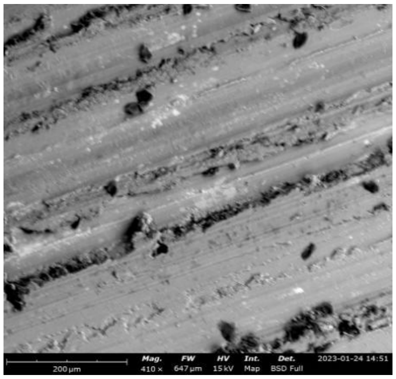

Fig.4 : Sample B (X410)

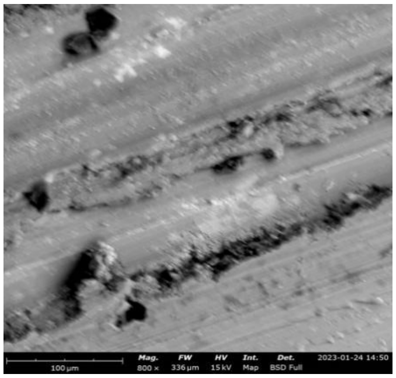

Fig.5: Sample B (X800)

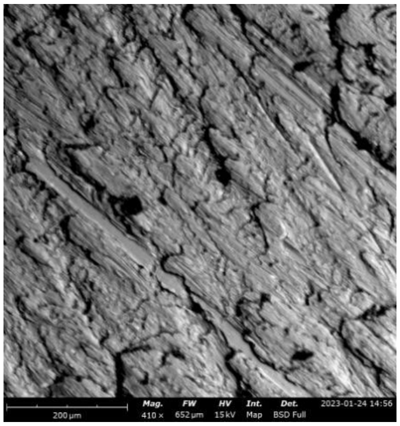

Fig.6 : Sample C (X410.)

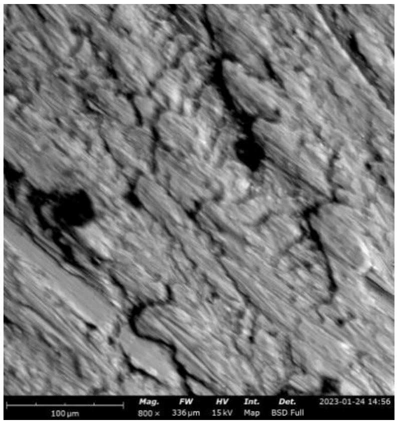

Fig.7 : Sample C (X800)

4. Discussion

It was observed that as the percentage of SiC and Fly Ash increases the tensile strength also increases. The compressive stress appeared opposite as the reinforcement increased. This can be explained in terms of solid solution mechanism where the solute or interstitial atoms are displaced by the reinforcing atoms. The hardness of the composite increased with the increase in weight fraction of the fly ash particles. Thus, the hard fly ash particles help in increasing the hardness of the aluminium alloy. The wear rate of the composite increases with increase in reinforcing materials. These findings were in accordance with the research of Kuye *et al.*, 2021 where it was mentioned that improvement of mechanical properties (hardness, impact, tensile, compressive and wear) caused by SiC particles.

The higher the weight of reinforcing material like Silicon Carbide and ash content the higher the tensile strength, the higher the Briness Hardness Value and the lower the Compressive strength. These findings tallied with earlier researchers as reported by Anilkumar *et al.,* 2006., Sandeep and Garg, 2012, who studied the effect of SiC & fly ash on Aluminum. Tensile Strength tends to increase with increasing SiC weight percentage in this investigation. Anilkumar *et al*., 2011 also reported that the hardness of the composite increased with the increase in weight fraction of the fly ash particles. Thus, the hard fly ash particles help in increasing the hardness of the aluminium alloy (Al6061) matrix. It was observed that as the percentage of SiC & Fly Ash increases the hardness also increases and the Sample B has high hardness.Vivekananthan1 and Senthamarai, 2011 reported that the effect of increased reinforcement on the wear behavior of the MMCs is to increase the wear resistance and reduce the coefficient of friction. The orange peel ash particulates were used to reinforce Al–Si–Mg alloy due to these results showed that there is a slight decrease in the mechanical properties because of poor adhesion of the reinforcement to that of the alloy (Shehu, 2011). The results obtained were in conformity with those of earlier researchers mentioned.

5. Conclusion

The major findings from the study carried out on the “Production and Characterization Of Aluminium Matrix Nano Composite From Silicon Carbide, Fly Ash And Orange Peel Ash” are as follows; The use of Silicon Carbide, Fly Orange Peel Ash are effective in improving the mechanical property of Aluminium metallic composites.

The tensile strength increases from 102 to 123 MPa with increase in reinforcing materials from 5 to 10% while compression strength of the specimens decreases from 24.689 to 22.810 kNm^2, hardness value from 38 to 42 HV and wear rate increase with same trend from 2.018 to 5.932 m^3/m.

The scanning electron microscope images of the samples revealed the Aluminium background and the intermetallic phases of SiC and the ash content.

References

Adetunji, O.R., Adedayo, A.M., Ismailia, S.O., Dairo, O.U. and Okediran, I.K. (2022)Effect of silica on the mechanical property of palm kernel shell based automotive brake pad, *Journal of Mechanical Engineering for Society and Industry,* 2(1):7-16,https://doi.org/10.31603/mesi6178, Published by Universitas Muhammadiyah Magelang, Malaysia

Ahamed, A.R. Asokan,P. Aravindan, S. (2009) EDM of hybrid Al-SiCp-B4Cp and Al-SiCp-Glassp MMCs, International Journal of Advanced Manufacturing Technology. 44(5-6) 520-528.

Aigbodion, V.S., Hassan, S.B., (2007). Effects of silicon carbide reinforcement on microstructure and properties of cast Al–Si–Fe/ SiC particulate composites. *J. Mater. Sci.Eng*. A 447, 355–360.

Aleksandar,V. (2009) "Scientific problems of machines operation and maintenance", Tribology Laboratory, Mechanical Engineering Faculty, University of Belgrade, 3 ; 159

Anilkumar, H.C. Hebbarand H.S. Ravishankar,K.S. (2011)"mechanical properties of fly ash reinforced aluminium alloy (Al6061) composites", *IJMME*, 2011, vol.6.

Arun L. R., Suneel K. Kulkarni, N. Kuldeep B, (2013) "Characteristic Studies on Aluminium Based Silicon Carbide and Fly Ash Particulate Metal Matrix Composite", 2013, *IJERT*, vol.2, issue-6.

Bedir, F. Ogel,B. (2004) Investigation of hardness, microstructure and wear properties of SiC-p reinforced Al composites. In: Proceeding of the 11th International Conference on Machine Design and Production, Turkey.

Bienia, J., Walczak, M., Surowska, B., Sobczaka, J. (2003) Microstructure and corrosion behaviour of Aluminium fly ash composites. *J. Optoelectron. Adv. Mater.* 5 (2), 493–502.

Britannica, T. Editors of Encyclopedia (2020, October 23). *Aluminum*. *Encyclopedia Britannica*. https://www.britannica.com/science/aluminum

Charles, D.(1990) "Metal Matrix Composites - Ready for Take-off?", *Metals and Materials,* Feb,78-82.

Chawla, N. Shen,Y.L. (2001) Mechanical Behavior of Particle Reinforced Metal Matrix Composites, *Advanced Engineering Materials.* 3(6) 357-37.

Demarker, S. (1986) "Metal Matrix Composites*", Metals and Materials*. 144-146.

Guo, R. and Rohatgi, P.K. (1997) "Fuel and energy Abstracts", 157 & 828.Neville AM. Properties of concrete. 4th ed. NY, USA: John Wiley & sons, Inc.; 1996

Harnby,N., Edward,M.F. and Nienow,A.W. (1985) "Mixing in Process Industries" (Butterworths, London).

Hassan S.B., Oghenevweta, J.E., Aigbodion, V.S., (2012) Morphological and mechanical properties of carbonized waste maize stalk as reinforcement for eco-composites. *J. Compos. Part B: Eng. Elsevier*, 43B (5), 2230–2236.

Kala, H., Mer, K. K. S., & Kumar, S. (2014). A Review on Mechanical and Tribological Behaviors of Stir Cast Aluminum Matrix Composites. Procedia Materials Science, 6, 1951-1960.

Kuye , S.I., Oladerin, K.O., Adetunji, O.R. and Makinde, V.O. (2021) Mechanical and Microstructural properties of Al-SiC Auto Brake Disc Rotor Composite, *Nigerian Journal of Materials Science and Engineering*, Vol. 11(2): 79-85

Lindroos V. K, Talvitie M. J (1995) Recent advances in metal matrix composites, *Journal of Materials Processing Technology*, 53:273-284.

Lindroos V. K, Talvitie M. J (1995) Recent advances in metal matrix composites, *Journal of Materials Processing Technology*, 53:273-284.

Luo A, Perquleryuz MO (1994). Review cast Mg alloy for elevated temperature applications. *J Mater Sci*; 29:5259-71.

Mahendra K.V. and Radakrishna. K. Castable, (2007), Castable composites and their application in automobiles, Proc. IMechE Part D: *J. Automobile Engineering,* 221: 135-140.

Matsunaga, T., Kim ,J.K. Hardcastle,S. and Rohatgi,P.K. (2002) Crystallinity and selected properties of fly ash particles, *Materials Science and Engineering* A325 ; 333–343

MECHTECH (2014). "Classification of Composite Materials." https://www.mechtechguru.com/2020/08/classification-of-composite-materials.html

Nagaral, M., Attar, S., Reddappa, H. N., & Auradi, V. (2015) "A Review on Particulate Reinforced Aluminium Metal Matrix Composites". *In Journal of Emerging Technologies and Innovative Research* (Vol. 2, No. 2 (February-2015)). JETIR.

Naresh, P. (2006) “Development and characterization of metal matrix composite using red Mud an industrial waste for wear resistant applications”, PHD thesis Department of Mechanical Engineering, *National Institute of Technology*

Negi, A.S., (2019) “A brief introduction to Aluminum Metal Matrix Composites” *Journal of Metallurgy and Materials Science*, 61(4), pp.161-184.

Ngo, T.D. (2020) “Introduction to composite materials. Composite and Nanocomposite, Materials From Knowledge to Industrial Applications”.

PACE TECHNOLOGIES (2006). “SiC particle in Aluminum Matrix” https://www.metallographic.com/Metallographic-Preparation-Procedures/SiC-aluminum-MMC.html

Rajaram G, Rao T. Srinivas, (2010) “High temperature tensile and wear behaviour of Aluminium silicon alloy”, *Materials Science and Engineering A* 528, pp. 247-253.

Rajaram G, Rao T. Srinivas, (2010) “High temperature tensile and wear behaviour of Aluminium silicon alloy”, *Materials Science and Engineering A* 528, pp. 247-253.

Ravichandran, M.V. Prasad, R.K. Dwarakadasa,E.S. (1992) “Fracture toughness evaluation of aluminium 4% Mg-Al2O3 liquid-metallurgy particle composite”, *Journal of Materials Science Letters.* 11(8) 452-456.

Rohatgi, P.K., Rajan, T.P.D., Pillai, R.M., Pai, B.C., Satyanarayana, K.G., (2007) “Fabrication and characterization of Al–7Si–0.35Mg/fly ash metal matrix composites processed by different stir casting routes” *Compos. Sci. Technol.* 67, 3369–3377.

Romeorim (2021), “Composite” https://romeorim.com/what-are-composites/

Sandeep K. R., Garg, T.K. (2012)“ Prepration & Analysis For Some Mechanical Property Of Aluminium Based Metal Matrix Composite Reinforced With Sic & Fly Ash”, *IJERA*, vol.2, issue6, pp.727-731.

Saravanan, R. A., & Surappa, M. K. (2000) “Fabrication and characterisation of pure magnesium-30 vol.% SiC P particle composite” *Materials Science and Engineering: A*, 276(1), 108-116.

Satyanarayana, K.G., Pillai, R.M. Pai,B.C. (2002), “Recent developments and prospects in cast aluminum matrix composites”,*Trans,Indian inst. metals* ,55(3), pp.115-130.

Shanmughasundaram, P. Subramanian, R. Prabhu, G. (2011)“Some Studies on Aluminium-Fly Ash Composites Fabricated by Two Step Stir Casting Method”, *European Journal of Scientific Research*,vol.63, pp.204-218.

Sharanabasappa R Patil, Prof B.S Motgi, (2013) “A Study on Mechanical Properties of Fly Ash and Alumina Reinforced Aluminium Alloy (LM25) Composites.”, *IOSR-JMCE*, vol.7, pp.41-46.

Shehu U. (2011) “Development of Al–Si–Mg/orange peels ash particulates ecocomposites for engineering applications”, Undergraduate research thesis submitted to the Department of Metallurgical and Materials Engineering, Ahmadu Bello University,Zaria.

Sidi, M.S. (2011) “Development of Al–Si–Mg/bean shell waste particulate”. Undergraduate research thesis submitted to the Department of Metallurgical and Materials Engineering, *Ahmadu BelloUniversity*.

Surappa, M. K., & Rohatgi, P. K. (1981). “Preparation and properties of cast aluminium-ceramic particle composites”. *Journal of materials science*, 16(4), 983-993.

Surappa, M.K..2011 “Aluminium Matrix Composites: Challenges and Opportunities”, *Sadhana* Vol. 28, Parts 1 & 2, February/April 2003, pp 319–334.

Trumper,R.L. (1987) "Metal Matrix Composites - Applications and Prospects". *Metals and Materials*. November, 662-667.

Tuti Y. A., and Haque, M.M. (2020) “Wear properties of aluminium – silicon eutectic alloy. in Wear Behavior of Al-Al_2O_3 Reinforced Composites/ Advanced Materials Research (Volumes 308 - 310)/ Advanced Design Technology.

Vencl A., (2009) “Scientific problems of machines operation and maintenance”,*Tribology Laboratory*, Mechanical Engineering Faculty, University of Belgrade, 3 ; 159, *Rourkela 769 008 (India),*January, pp. 23–34.