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PERFORMANCE AND EMISSION CHARACTERISTICS OF CI ENGINE USING WASTE COOKING OIL BIODIESEL BLENDS WITH ADDITION OF AL₂O₃ NANO- PARTICLES



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PERFORMANCE AND EMISSION CHARACTERISTICS OF CI ENGINE USING WASTE COOKING OIL BIODIESEL BLENDS WITH ADDITION OF Al_2O_3 NANO-PARTICLES

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Abstract

The renewable energy sources have gained their importance from last few decades. The enhanced environmental concerns & exhaustion of fossil fuels reserves has inspired the researcher to find alternative energy sources. The biodiesel obtained from Vegetable oil & animal fat is recommended for replacement of conventional fuels. The use of Waste Cooking Oil is economical and makes the biodiesel competitive in price with petroleum based fuels. The current study is aimed to study the influence of Aluminium oxide nano additives on the performance and emissions characteristics of compression ignition engine fueled with waste cooking oil bio-diesel. In the experimentation, 50ppm & 100ppm of Aluminium oxide nano-particles were mixed in waste Cooking Oil biodiesel. Experiments were carried out with B20WCOME and adding Aluminium oxide nano particles in the proportion of 50ppm & 100ppm respectively to B20WCOME biodiesel blend. The results revealed that, the brake thermal efficiency increased and specific fuel consumption has reduced for B20WCOME & B20WCOME nano additive blends. When compared with diesel, there is a significant reductions in the parameters like UBHC, NO_x and CO emissions for B20WCOME in conjunction with 50ppm & 100ppm Aluminium oxide nano-additive blends. However, there is a slight increase in NO_x emissions for B20WCOME & B20WCOME nano additive blends.

Keywords: CI Engine, Waste Cooking oil Biodiesel, Aluminium Oxide nano particles

1. Introduction

Globally, the fossil fuels have been considered as main energy resources from last several decades. The petroleum based fuels are non-renewable sources & these sources will be depleted soon due to growing population and increased industrialization. The extreme use of these non-renewable sources has caused many negative implications to the environment. This has made us to


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EFFECT OF AL₂O₃ AND CeO₂ NANO-ADDITIVES ON PERFORMANCE AND EMISSION CHARACTERISTICS OF DIESEL ENGINE FUELED WITH NEEM OIL-BIODIESEL

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Effect of Al_2O_3 and CeO_2 Nano-Additives on Performance and Emission Characteristics of Diesel Engine Fueled with Neem Oil-Biodiesel

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Abstract

Due to the rapid depletion of petroleum reserves, many countries recommended the use of vegetable oils as diesel engine fuel. The best way to use edible and non-edible oil as a diesel fuel is to convert it into biodiesel. Biodiesel is a fuel which can be used instead of diesel fuel as an alternative for the existing system of CI engines. The usage of biodiesel causes a few disadvantages like high nitrogen oxides, utilization of high fuel and higher density. To conquer these problems some promising nano-additives are identified for having been used in the production of biodiesel. However, the addition of Nanoparticles will possibly enhance the performance and reduce the emissions. Therefore, the present investigation focuses on the influence of Al_2O_3 and CeO_2 nano-additives on the performance and emissions characteristics of CI engine fueled with methyl esters of Neem. As nano-additives Al_2O_3 and CeO_2 contain high oxygen content, it leads to complete combustion of fuel thereby increasing performance and reducing the oxide formation. In the experimentation, 50ppm, 100ppm of Al_2O_3 and CeO_2 nano-additives were mixed in methyl esters of Neem. Subsequently, the fuel blends of Neem biodiesel (B20N) alone and Neem biodiesel with 50ppm, 100ppm of Al_2O_3 and CeO_2 nano additives in CI engine were employed. The results revealed that, there is a increase in the break thermal efficiency and decrease in specific fuel consumption for B20N and B20N additive blends. Significant reductions in the parameters like CO, UBHC and NO_x emissions are attained at B20N in conjunction with 50ppm, 100ppm of Al_2O_3 and CeO_2 Nano-additives blends as compared with diesel. However, there is a slight increase in NO_x emissions for B20N and additive blends.

Keywords: Al_2O_3 Nano-Additive, CeO_2 Nano-Additive, CI Engine, Neem Biodiesel

1. Introduction

Internationally, there has been a tremendous establishing over the Globe in last two decades. The population of motor vehicles in India is about one hundred million. This has increased the need for fossil fuel. Due to the exhaustion

of fossil fuel, the world is facing the inadequacy of energy and rise of petroleum price. 'Transportation' section is distinct and is mainly depending upon the petroleum fuel. This will greatly affect the country's economy. Petroleum based fuels are non-renewable energy sources and cannot be restored again. Because of ever growing population,

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FLUID FLOW IN COMPOSITE REGIONS PAST A SOLID SPHERE

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Fluid Flow in Composite Regions Past a Solid Sphere

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Abstract: A steady, 2-D, incompressible, viscous fluid flow past a stationary solid sphere in a porous medium has been considered. The flow of fluid occurs in 3 regions, namely, fluid past a solid sphere, porous medium, and porous medium. The governing equations for fluid flow in the clear and porous regions are Stokes equation and Brinkman equation, respectively. These governing equations are written in terms of stream function in spherical coordinate system and solved using the similarity transformation technique. The streamlines are plotted by means of streamlines has been analyzed for the obtained exact solution. The velocity profiles and the corresponding tangential and normal velocity profiles are observed and plotted for various values of porous parameter 'n'. From the obtained results, it is noticed that as the value of porous parameters suppresses the fluid flow in the porous region and the fluid flow moves away from the solid sphere. It also decreases the velocity of the fluid in the porous region as the suppression of the fluid as 'n' increases. Hence the fluid flow is suppressed in the porous region of the sphere.

Keywords: fluid flow, Brinkman equation; Stokes equation; interface boundary; permeability parameter.

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1. Introduction

The fluid flow through the porous medium is of considerable interest as it is important in natural occurrence. It has great significance in the fields of industrial, geophysical, and biomedical uses. The porous medium is used in chemical industries to obtain a powerful mixing process, filtration, purification, and oil recovery. In nuclear industries, it has been used for effective insulation and emergency cooling of nuclear reactors. In the bio-medical field, to understand the transport process of lungs and kidneys, the flow of fluid through porous media is essential.

IMPROVED PHOTOLUMINESCENCE AND SPECTROSCOPIC FEATURES OF SM3+ DOPED ALKALI BORATE GLASSES BY EMBEDDING SILVER NANOPARTICLES

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IMPROVED PHOTOLUMINESCENCE AND SPECTROSCOPIC FEATURES OF SM3+ DOPED ALKALI BORATE GLASSES BY EMBEDDING SILVER NANOPARTICLES

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Improved photoluminescence and spectroscopic features of Sm^{3+} -doped alkali borate glasses by embedding silver nanoparticles

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Abstract

Influence of Ag nanoparticles (NPs) on the improvement in photoluminescence and spectroscopic features of Sm^{3+} -doped alkali borate glass synthesized by the melt quenching process was systematically studied and analyzed. The increasing particle size of Ag NPs with the increase of AgCl concentration (0.1 – 0.5 mol%) causes the surface plasmon resonance peak to shift to a higher wavelength (red-shift) side. Electron microscopic investigation confirmed the presence of silver NPs in the SmlAB-1 glass sample with a median size of 4.57 nm. A significant enhancement in emission was noticed for 0.1 mol% AgCl concentration. Such improved emission was attributed to the enhanced local electric field by metallic NPs in the vicinity of Sm^{3+} ions and efficient energy transfer between Sm^{3+} ions and silver NPs. The Judd–Ofelt parameter, Ω_2 , decreased as the concentration of Ag NPs increases, indicating increased symmetry and ionicity between the trivalent samarium ions and their ligands. These prepared glass compositions could have applications in solid-state devices such as LEDs and display applications.

Introduction

In recent years, borate-based oxide glass family has received relatively more interest than other glass families owing to its cost-effectiveness, low melting point, better thermal and chemical stability, better rare earth (RE^{3+}) ion solubility, and excellent transparency in the ultraviolet (UV) and near infrared (NIR) wavelength ranges [1,2]. However, pure borate hosts are extremely hygroscopic in nature which exaggerated in the functioning of glasses [3]. The hygroscopic nature, chemical and mechanical stability increases when lanthanum and alkali oxides are incorporated into the borate glass network [4,5]. Thus, alkali borate glass hosts are regarded as one of the best candidates for photonic device applications [6,7]. RE^{3+} ion-activated inorganic glass hosts have been widely accepted in the design of optoelectronic devices such as light converters, lasers, optical fibers, and high-density memory optical amplifiers [8]. It is well known that the fluorescence properties and excitation of RE ions are strongly correlated with the phonon energy of the host, symmetry, and structure of the surrounding environment. Among all the lanthanide ions, the tri-valent samarium (Sm^{3+}) ions are of interest for the investigation due to its strong emission in visible reddish-orange region due to $f-f$ transitions. Therefore, the Sm^{3+} ions doped glass matrices have been widely investigated for color displays, plasma displays, undersea communication, solid-state devices, high-density optical memories, visible lasers etc. [9]. Of all the emission transitions of Sm^{3+} , the transition due to ${}^4G_{5/2} \rightarrow {}^6H_{7/2}$ gives the emission in the visible region owes strong emission intensity with excellent emission cross-section [9]. This emission from excited Sm^{3+} : ${}^4G_{5/2}$ state is of relatively high quantum efficiency; however, it depicts the quenching mechanisms at higher concentrations [10]. Recently, embedding metal nanoparticles (MNPs) into RE-routed glasses has emerged as a promising approach for enhancing the emission efficiency of RE^{3+} ions. MNPs may influence RE^{3+} ion emissions in a variety of ways. The local field enhancement stimulated by surface plasmon resonance (SPR) of MNPs has been attributed as a possible cause of luminescence improvement when the excitation or emission of MNPs is resonant or near the SPR. Furthermore, the energy transfer from MNPs to RE ions has also been reported [8]. In particular, noble MNPs such as Au, and Ag along with Cu are commonly utilized to improve the RE^{3+} ion emission efficiency and glass performance. In addition, when stimulated with electromagnetic radiation and constrained near the sharp boundaries of anisotropic nanostructures that serve as light-harvesting nano-optical channels to convert electromagnetic radiation into a huge localized electric field and there by local surface charge densities are enhanced significantly. Inorganic glasses have also been shown to


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IMPROVED NEAR-INFRARED NONLINEAR OPTICAL PROPERTIES OF SM3+ CONTAINING BORATE GLASSES: EFFECT OF SILVER NANOPARTICLES CONCENTRATION

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Improved near-infrared nonlinear optical properties of Sm^{3+} containing borate glasses: Effect of silver nanoparticles concentration

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ABSTRACT

Efficacy of silver nanoparticles on tuning the optical nonlinear characteristics of Sm^{3+} doped borate-based glasses has been investigated comprehensively and the outcomes are provided. The nonlinear optical (NLO) attributes were retrieved using the Z-scan technique under an ultrafast pulse excitation with the wavelength ranging from 700 nm to 1000 nm. Reverse saturable absorption (RSA), ascribed to two-photon absorption, was realized in open aperture Z-scan profiles whereas refraction nonlinearity of positive type due to the self-focusing was observed in closed aperture Z-scan data. Based on the Z-scan results along with the figure of merit condition (higher than unity), it was identified that the silver nanoparticles embedded Sm^{3+} containing glass hosts are competing materials for NLO device applications to function in near-infrared region.

1. Introduction

The nonlinear optical (NLO) properties of several materials (solids, liquids, nanomaterials, crystals etc.) have now been investigated for over 20 years. The assessment of NLO features of materials is beneficial for demonstrating their suitability to use in many applications such as frequency-up conversions, 3D microfabrication, optical limiters, passive mode locking, generation of pulses, high-speed electro-optic modulators, bioimaging, and optical switches [1,2]. The fast development in the communication and laser industry has urged the growing need for new materials that possess high optical nonlinearities for the effective functioning of devices. This has created a tremendous interest in NLO properties of materials [3]. Different materials possessing large

NLO coefficients have been investigated to date. However, the low thermal decomposition and difficulty in preparing them in large scale hinders their practical utility in the actual device fabrication. These limitations can be overcome in glasses [4]. In addition, the glasses are highly isotropic compared to different materials investigated to date. Therefore, glass systems possess high order optical nonlinearities which is also crucial for the practical use in the device fabrication. Interestingly, the NLO attributes of the glass matrices can be tuned significantly to meet the requirement of devices by merely modifying the composition without losing the glass formation [5].

Among all other glass families, the borate glasses are found to possess large optical nonlinearities along with high laser damage threshold [6]. Enhancement of NLO characteristics of the glassy materials can be

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NEAR-INFRARED NONLINEAR OPTICAL CHARACTERISTICS OF SILVER NANOPARTICLES EMBEDDED BORATE GLASSES ACTIVATED WITH SM3+ IONS: EFFECT OF HEAT TREATMENT

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Near-infrared nonlinear optical characteristics of silver nanoparticles embedded borate glasses activated with Sm^{3+} ions: Effect of heat treatment

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ABSTRACT

The impact of heat treatment on the nonlinear optical (NLO) features of silver nanoparticle-embedded Sm^{3+} ion-containing glasses prepared by the melt-quench method has been investigated and discussed in detail. The NLO coefficients were assessed by the Z-scan method in the near-infrared spectral region using femtosecond, MHz laser pulses. The magnitude of different NLO coefficients, such as two-photon absorption (β) and nonlinear refractive index (n_2), have been shown to be elevated with the heat treatment. Typically, at 800 nm excitation, the two-photon absorption coefficient increased from 0.816×10^{-11} m/W to 1.282×10^{-11} m/W, and the n_2 values increased from 1.896×10^{-19} m²/W to 2.376×10^{-19} m²/W as the heat treatment duration was increased from 10 to 25 h. This improvement in the NLO properties was ascribed to the local field effects stimulated by the silver nanoparticles. The obtained results suggest that the investigated glasses serve as good hosts for fabricating devices such as optical switches and limiters.

1. Introduction

Rare earth (RE) ion-doped glass hosts have been investigated by material scientists over the past few decades to demonstrate their utility in many optoelectronic and photonic devices such as optical amplifiers, displays, LEDs, and solid-state lasers [1,2]. This is due to the fact that the light emitted by RE ions (due to 4f-4f transitions in RE ions) when excited by a suitable wavelength is intense. The intensity of the emitted radiation depends on several factors such as the structure of the glass, the host's phonon energy, the ligand field around the RE ions, and the surrounding network of the RE ions. Furthermore, the emission intensity also depends on the RE ion concentration. It is understood that the

emission intensity cannot increase continuously with an increase in the RE ion concentration and displays quenching at higher doping levels [2]. In addition to photoluminescence (PL) investigations devoted to demonstrating RE-doped glasses for photonic devices, nonlinear optical (NLO) investigations on RE-doped glasses have received significant interest in the recent past [3,4]. Interestingly, the outer shell valence electrons and hyperpolarizability of RE ions enhance the NLO properties of the parent glasses [5]. Therefore, RE-doped glasses have been demonstrated for NLO device applications such as power optical limiters, optical switches, communication fiber optic systems, and passive mode locking applications [6].

Furthermore, metal nanoparticle embedded (MNP) glasses have been

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SILVER NANOPARTICLES ENHANCED PHOTOLUMINESCENCE AND THE SPECTROSCOPIC PERFORMANCES OF ND³⁺ IONS IN SODIUM LANTHANUM BORATE GLASS HOST: EFFECT OF HEAT TREATMENT

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Silver nanoparticles enhanced photoluminescence and the spectroscopic performances of Nd³⁺ ions in sodium lanthanum borate glass host: Effect of heat treatment

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Infrared lasers

ABSTRACT

Silver nanoparticles (NPs) impact on the emission attributes of Nd³⁺ activated Na₂O–La₂O₃–B₂O₃ vitreous host matrix has been studied and discussed in detail. The effect of nucleation and growth of Ag NPs occurred due to the different heat-treatment durations at the temperature of 450 °C has been discussed. Transmission electron microscopy measurement revealed the formation of spherically shaped Ag NPs in the studied samples. The median Ag NPs size was increased from 2 to 9 nm with heat-treatment durations. Utilizing the absorption spectra of Nd³⁺ ions, the phenomenological Judd–Ofelt (J–O) parameters (Ω_{λ} , $\lambda = 2, 4, 6$) were estimated. The optimized luminescence intensity at 1056 and 875 nm have realized for 10 h of annealing at 450 °C, with an enhancement factor of 160%. Moreover, the quantum efficiency for 1056 nm increased steadily with the heat-treatment duration. The stimulated emission cross-section and gain bandwidth for 1056 nm laser transition has shown to be 2.92×10^{-20} cm² and 9.19×10^{-26} cm³ for the Ag NPs embedded glass-composite. The results exemplifies the suitability of Ag NPs embedded glass-composites for the fabrication of compact solid-state infrared lasers.

1. Introduction

The studies on neodymium (Nd³⁺) doped oxide glass embedded with silver nanoparticles have received significant interest in recent past due to their utilizations in infrared (NIR) lasers, high-density optical storage devices, and medical diagnostics, etc., [1,2]. The advantage of the large emission cross-section of Nd³⁺: $^4F_{3/2} \rightarrow ^4I_{11/2}$ transition at 1056 nm could be exploited by stimulating Nd³⁺ ions at 808 nm. Moreover, Nd³⁺-doped laser materials have interesting features such as higher gain cross-sections and 4-levels laser operation mode, in compare to Yb³⁺-doped solid state laser materials [3].

Studies have manifested the reduction process and ion exchange to explain the growth of Ag NPs in glass matrix [4,5]. Authors have

claimed that under the matching of ionic radius, the successful substitution of anions of the glass matrix by Ag⁺ ions; however, it has the challenge of meeting the requirements of technological demand [6]. Moreover, the occurrence of metal NPs embedded in glass host is of great curious owing to their improved optical properties and finds applications in photonic devices [7,8]. The glass systems embedded with Ag NPs are of particular interest because of their remarkable photonic attributes like the excellent emitting efficiency and transparency of the glass. The feasibility of controlled tailoring of size and structure of Ag NPs has offered the opportunity to tailor their optical properties, for various photonic-device-based applications [9,10]. Furthermore, the rare earth ions emission intensity in glasses can be

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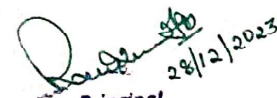
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(17)

INFLUENCE OF SIZE OF Ag NP ON SPECTROSCOPIC PERFORMANCES OF EU3+ IONS IN SODIUM BORATE GLASS HOST

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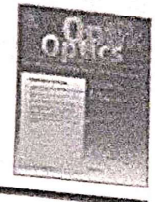
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Original research article

Influence of size of Ag NP on spectroscopic performances of Eu³⁺ ions in sodium borate glass host

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ABSTRACT

In this contemporary technological world, Eu³⁺ ions doped metal nanoparticles embedded amorphous materials are receiving overwhelming interest due to their potentiality in developing LEDs and solid-state lasers for photonic devices applications. Due to which, in the present investigation, we made an attempt to enhance the spectroscopic performance of Eu³⁺ ions in the proposed glasses. A new set of Eu³⁺ ions doped Ag NPs precipitated sodium borate glasses were fabricated using a simple conservative melt quenching method. The results of XRD support the glasses' amorphous phase by exhibiting a large diffuse ring at 20–40°. The optical absorption spectra results reveal that the observed absorption peaks originated from ⁷F₀ and ⁷F₁ ground states to various excited states of Eu³⁺ ions and as usual the observed SPR peak induced by Ag NPs underwent regular red-shift. The presence of spherical and well-dispersed Ag NPs in the glass matrix was confirmed by HR-TEM images. PL emission spectra of the studied glass samples showed that the highest peak emission intensity for NLE-1 glass, and also observed that the enhanced peak intensities for all NLE glasses with precipitation of Ag NPs. This PL intensity improvement is due to the transfer of energy from small clusters of Ag NPs to Eu³⁺ ions. The yield of the ⁵D₀→⁷F_J emissions is demonstrated utilizing the 1931 CIE chromaticity diagram. In addition, the emission of Eu³⁺ ions has been analyzed using the Judd-Ofelt emission theory.

1. Introduction

In recent decades, rare earth (RE³⁺) ions doped amorphous materials become one of the emerging fields in photonic devices applications due to their most important unique characteristic features such as tunable phosphors, favorable for lasing action, possess good optical nonlinear properties and varied index of refraction [1–3]. Which are beneficial for the development of LEDs, lasers, fiber-optic communications, display devices, etc. [4–7]. The glass hosts are found to have a significant influence on the spectroscopic performance of the RE³⁺ ions thanks to the perception of electronic excitations and relaxation mechanism with the contribution of two, and more active centers [8]. Electronic transitions of RE³⁺ ions have shown ample multicolored luminescence within 4f → 4f transitions, which are usually found to be photostable, long-lived and sharp [9]. The coupling of metal nanoparticles (MNPs) with RE³⁺ ions has been extensively studied for the past few years and is an excellent technique for improving the emission efficiency of RE³⁺ ions. MNPs in the glass matrix may influence the luminescence properties of RE³⁺ ions in two distinct pathways. One way the local field

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PERFORMANCE OPTIMIZATION AND EMISSION CHARACTERISTICS OF CI ENGINE FUELLED WITH BLENDS OF WASTES CHICKEN FAT BIODIESEL WITH EXHAUST GAS RECIRCULATION

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PERFORMANCE OPTIMIZATION AND EMISSION CHARACTERISTICS OF CI ENGINE FUELLED WITH BLENDS OF WASTES CHICKEN FAT BIODIESEL WITH EXHAUST GAS RECIRCULATION

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ABSTRACT

Demand for fuel and the use of petroleum products are being increased gradually which causes serious problems such as petroleum depletion, energy crisis and environment degradation etc. Consequently, at this juncture, biodiesel is found to be a good alternative and a promising conventional diesel fuel. Subsequently, the application of biodiesel not only fulfilling the gap of energy catastrophe but, also proffers some shortcomings such as high oxides of nitrogen, high fuel consumption and higher density. Therefore, in order to prevail over this problems and reducing exhaust emission, the study has been undertaken to demonstrate the study on Emission Characteristics of a CI Engine fuelled with Wastes Chicken Fat Biodiesel (WCFB) blends with Exhaust Gas Recirculation (EGR). In the study, initially, Biodiesel is obtained from Chicken fat oil as a result of transesterification process. The experiment work was done on a CI-Engine using a biodiesel (trial with variable blends) achieved by Chicken fat oil with Exhaust Gas Recirculation (@30%). Further, the performance and emission characteristics of all the blends were carried-out and were compared decisively with petro-diesel. The experimental results shows that, the enhanced Performance and Emission characteristics with B20 biodiesel blend and the momentous reduction in NOX emission using Exhaust Gas Recirculation approach was observed. In addition, the thermal efficiency was increased and SFC (Specific fuel consumption) was found to be better in blending fraction of WCF Biodiesel. A noticeable approach on the parameters like, decrease in carbon monoxide reduced unburned hydrocarbon (UBHC) and decreases in nitrogen oxide emissions are attained at the blending fraction of B20 biodiesel when compared with petro-diesel. Hence, there is a significant reduction in CO, UBHC and NOx emission parameters at B20 biodiesel blending ratio coupled with Exhaust Gas Recirculation (EGR) system. However, the EGR level was optimized (30%) with respect to the performance of CI Engine linking with significant reduction in the emission of NOX, minimum possible smoke, CO, HC emissions and corresponding with brake thermal efficiency.

KEYWORDS: Waste Chicken Fat Biodiesel, Performance Optimization, CI Engine & EGR

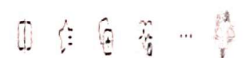
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LIST OF SYMBOLS

- BTE: Brake Thermal Efficiency
- SFC: Specific Fuel Consumption
- CI Engine: Internal Combustion Engine
- NOx: Oxides of Nitrogen
- CO: Carbon Monoxide
- HC: Hydrocarbon

ANTICANCER STUDIES OF CO(II), NI(II) AND ZN(II) COMPLEXES OF 6-PYRIDYL-5,6-DIHYDROBENZO[4,5]-IMIDAZO[1,2-C] QUINAZOLINE (N-N)

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NUMERICAL STUDY OF MICROPOLAR FLUID FLOW PAST AN IMPERVIOUS SPHERE



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Numerical Study of Micropolar Fluid Flow Past an Impervious Sphere

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Keywords: Micropolar fluid, variable co-efficient, similarity transformation, shooting technique

Abstract. The numerical study of axis-symmetric, steady flow of an incompressible micropolar fluid past an impervious sphere is presented by assuming uniform flow far away from the sphere. The continuity, linear and angular momentum equations are considered for incompressible micropolar fluid in accordance with Eringen. The governing equations of the physical problem are transformed to ordinary differential equation with variable co-efficient by using similarity transformation method. The obtained differential equation is then solved numerically by assuming the shooting technique. The effect of coupling and coupling stress parameter on the properties of the fluid flow is studied and demonstrated by graphs. It is noticed that the viscous sublayer reduces and velocity magnifies with increase in coupling number. Also, the dimensionless shearing stress varies at front and rear stagnation points for the variation of the coupling number and stress parameter.

Citation

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04

MAXIMIZING NETWORK LIFETIME USING FUZZY BASED SECURE DATA AGGREGATION PROTOCOL (FSDAP) IN A WIRELESS SENSOR NETWORKS



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Maximizing Network Lifetime using Fuzzy Based Secure Data Aggregation Protocol (FSDAP) in a Wireless Sensor Networks

Reshma S, Shaile K, Venugopal K R

Abstract: Abstract: Secure Data Aggregation in Wireless Sensor Networks (WSNs) is a challenging issue. The various protocols has been suggested in the recent past such as EDIT[13], ADA[8], TSDA[9], SEDAN[10]. These protocols effectively meet the constraints of WSNs. In this paper, we have proposed a Fuzzy Based Secure Data Aggregation protocol (FSDAP) which is an efficient localized protocol. The FSDAP protocol is designed with three phases. The first phase selects Aggregator Node using ANS algorithm. An ANS algorithm involves two steps to elect an Aggregator Node in the clustered network. In first step, the cluster head is selected based on the Euclidean distance and in second step, the cluster head is selected based on the fuzzy product and fuzzy value (α). Then, in second phase, a selected AN eliminates data redundancy sensed by all sensor nodes within the cluster. Finally, in third phase, the FSDAP protocol effectively detects malicious node and provides secure data transmission path. Thus, the proposed protocol, FSDAP utilizes the node's resource parameter uniformly, which in turn improves Network Lifetime, maximizes Throughput Rate, maximizes Packet Delivery Ratio and minimizes End-to-End Delay. The FSDAP is simulated using the NS2 simulator and compared with centroid algorithms Fuzzy C-Means and K-Means algorithm and a secure aggregation protocol implemented using SAR (Secure Aware Ad hoc Routing). The time complexity of FSDAP protocol is $O(m2n)$.

Keywords: Data Aggregation, Data Transmission, Fuzzy, Malicious Node, Localized, Network Lifetime, Wireless Sensor Networks.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) consists of a large number of tiny sensor nodes and one or more base stations. The tiny sensor nodes are capable of sensing, processing and sending an event to the base station.

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Health care[4], Machine Surveillance and Preventing The sensor nodes are battery powered and limited resource constrained devices.[1][2]. So, it is necessary for the WSNs applications to utilize the resource effectively WSNs have diverse applications viz., Disaster relief operations, Biodiversity mapping, Intelligent building[3], Maintenance [5][6]. For example, the environmental conditions are measured using spatially distributed independent sensor nodes and can be accessed by the user as shown in Fig. 1. The real-world applications collect data from multiple sensor nodes. The sensor nodes sense redundant data and transmit to the base station. The redundant data transmission consume more energy[7] and depletion of more energy in the network results with network partition. Therefore, the practical solution is to aggregate the sensed data before data transmission. Hence, it is necessary to elect an efficient Aggregator Node (AN).

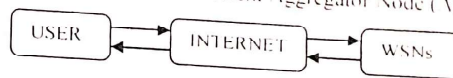
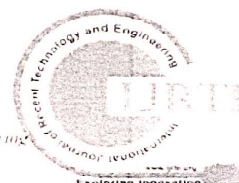


Fig. 1: Wireless Sensor Networks (WSNs) Infrastructure

There are various data aggregation protocols viz., Tree - Based, Cluster - Based and Hybrid Data aggregation[8][9] that are used to elect an efficient AN. In cluster-based data aggregation protocols[10][11][12], the aggregator node is elected based on distance and residual energy and EBRP[13] protocol elects the Aggregator Node (AN) based on energy density, residual energy and distance. Mahalanobis distance, membership value and Fuzzy C-Means algorithm to extract ellipses from the cluster are used in [14]. Thus, it covers the whole network and avoid holes in network and thus guarantees data delivery to the base station. The objective of the aggregation protocols is to minimize the redundant data transmission and maximizes Network Lifetime. The aforementioned aggregation protocols minimize redundant data transmissions in network [15][16] and prolongs Network Lifetime. But various aggregation protocols efficiently do not meet the resource constraints.

In addition to data aggregation, it is also necessary to provide security for successful data delivery to the base station with effective utilization of available resource parameters. There are various security attacks [17] viz., snooping attack, worm hole attack, black hole attack, packet replication attack, Denial-of-Service (DoS) attack, Distributed DoS (DDoS) attack, etc.



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HYBRID DOMAIN STEGANOGRAPHY FOR MULTIPLE IMAGES USING DWT-LSB METHOD

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Hybrid Domain Steganography for Multiple Images using DWT-LSB Method

Shashikiran B S, Shaila K, Venugopal K R

Abstract: The technique of hiding information with coexistence of other information is called Steganography. Users usually stores their documents in the form of images so this can be achieved using steganography. Image steganography can be performed in spatial-domain, Transformation-domain and hybrid domain. A new hybrid domain based steganography for hiding multiple image in a single image is proposed in this paper. The properties of Discrete wavelet transforms is used for developing the algorithm that provides security and also reduces the storage capacity in huge databases. While storing various documents of a user in a huge database confidential and integrity has to be Maintained. Possibility of mismatching of document in huge databases is very common and data storage for maintaining those documents are challenging task. In this Approach, multiple secret images are embedded in a single cover image to get stego image using hybrid domain. Discrete Wavelet Transform (DWT) and Least Significant Bit (LSB) techniques are used in embedding multiple images that reduces the storage capacity along with, enough security. The proposed algorithm provides acceptable Peak Signal to Noise Ratio (PSNR) ratio and data capacity of hidden information is more compared to existing methods.

Keywords : Cover Image, DWT, LSB, PSNR, Secret Image Steganography, Stego Image

1. INTRODUCTION

Steganography [1-3] is a technique of embedding data such that it doesn't draw the attention of the hackers. Steganography means covered writing and is originated from two Greek words with 'Steganos' means covered and 'graphia' means writing. In cryptography data is hidden by scrambling it so that it is unreadable but gives a clue to the hacker.

In recent era, information exchange takes place electronically where new issues, requirements and opportunities are emerged. It is intended that only the authorized person has rights over the data during communication so that unauthorized persons cannot seize the information. Hence, steganography is used to hide the data in other data for secure communication. Consider a person who wishes to deliver some information to recipient such that no one else knows about the information, this can be achieved using steganography technique.

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Different types of steganography methods used for embedding information are:

Text Steganography: It allows the user to embed text behind other files by altering the format of text or a file to generate an arbitrary character within the text file. In this technique a text file is preferred as a cover media wherein the secret data is embedded. In this technique, the data is more susceptible to the hackers. Since, the hacker recognize the pattern and decodes the secret data easily. The process of text steganography is difficult since it lacks a large-scale redundancy of information when compared to audio, image and video-based steganography.

Image Steganography: The image steganography technique has gained much attention in the field of steganography. Image steganography techniques are of three types:

1. **Spatial-Domain Steganography:** In this some bits of both cover image and secret image are directly manipulated for embedding secret data.
2. **Transformation-Domain Steganography:** The first and foremost thing is to convert the spatial-domain images to transformation-domain and then embeds the secret data.
3. **Hybrid-Domain Steganography:** Both spatial domain and transformation-domain techniques are employed for hiding secret image in cover image. Initially cover image is converted to Transformation-domain and then the concept of spatial-domain is applied to hide the secret image.

Video Steganography: Embedding information in a video is similar to image steganography where different frames of video are considered to embed information in it.

Audio Steganography: The Audio steganography is most interesting technique as it involves Human Auditory System. Best way to achieve the audio steganography is to use Ultrasound range to transmit secret information.

The aim of this work is to hide the information in image by providing security and to reduce the storage capacity in huge databases. Consider, a bank where customer's data like, account details, photo, Aadhar, PAN and few more details has to be collected and maintained in database. Similarly, in defense, medical field, colleges, some public and private sectors where multiple data of a person or user are stored in databases as image. First, the database is secured using cryptography. If at all hackers can attack and get information about individuals steganography provides the security at next

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Reckoning Network Lifetime Ratio for Wireless Sensor Network

Mohamed Najmus Saqhib, Lakshmikanth .S

Abstract: Advanced Technologies such as Internet of Things, Machine Networking give rise to the deployment of autonomous Wireless Sensor Nodes. They are used for various domains namely battlefield monitoring, enemy detection and monitoring the environment change. These Wireless Sensor Nodes have the properties of low cost and high battery life. NL (Network Lifetime) is an important phase of Wireless Sensor Network (WSNs), in which the nodes can maintain sensing for a more amount of time. NL can be improved by use of multiple techniques namely Opportunistic Transmission, Scheduling of Timed Data Packets, Clustering of Nodes, Energy Harvesting and Connectivity. This paper provides the energy consumption computation, life time ratio definition and the overview of NL improvement techniques. The paper also presents brief review of the Destination based and Source based routing algorithm.

Keywords— Energy Harvesting, Lifetime Ratio, Wireless Sensor Network, Network Lifetime, Beam forming

I. INTRODUCTION

Wireless Sensor Networks (WSNs) can be classified into cluster based network and single area random networks. Cluster based network will divide the entire area into a set of sub-areas. Each of the area will have a set of nodes. One among the node is chosen as the cluster head for communication between nodes of different clusters [1]. In order to have a better aerial communication a new application layer is provided which will have ContikiMAC layer along with IEEE 802.15.4 2.4 GHz physical layer. With this modification better efficiency energy, high reliability is obtained [2]. The information needed for placement of multiple target sources is provided by acquisition of Received-signal-strength (RSS) values with the help of inexpensive sensors. Three algorithms are used to estimate the value of transmission power, location and orientation of target sources [3]. WSNs have higher advantage as compared to wired networks with respect to flexibility and easy access. Sequential Scanning is responsible for scanning of channels one by one, sensor nodes will be divided into subset and for each subset sequential scan is performed and the last approach will make use of randomized approach in which channel is assigned a random value [4] Wireless Medical Sensor Networks (WMSNs) will be used for remote patient monitoring. The characteristics of environment are delay sensitivity and critical data.

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When the data is transmitted to the actual intended node at regular intervals at a higher rate causes issues like packet drops, retransmissions, and collisions [5]. Exponential cat swarm optimization (ECSO) [6] combines two algorithms. The first algorithm is exponential weighted moving average, and second algorithm is cat swarm optimization (CSO). In this algorithm cluster head is opted based on fuzzy-based ant colony optimization (PFuzzyACO) which computes fuzzy ACO and penguin search optimization. The optimized routing algorithm finds an efficient route between the initiate and terminate node based on multiple parameters namely trust computation, energy value, delay value and density based computation of traffic. The taxonomy of applications in actual WSN applications is summarized in Fig 1.

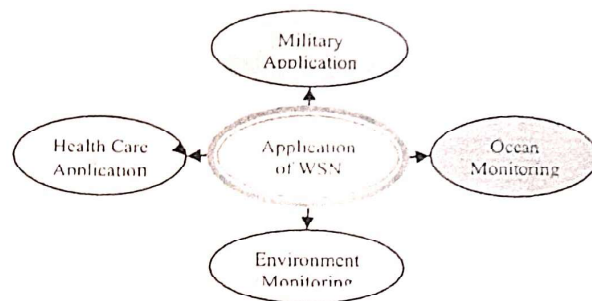


Fig1: Application of WSNs

Fig 1 shows the applications in which WSN is used in a large amount namely Military, Health Care, Ocean Monitoring and Environment monitoring.

II. CLASSIFICATION OF WSN

The broad classification of network is described in Fig. 2. There are two kinds of classification. The first kind is single area network and then second kind is cluster based network.

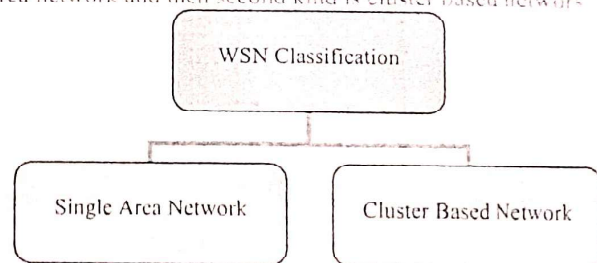
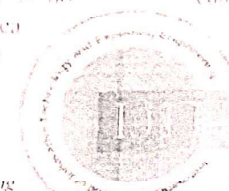


Fig2: Classification of Wireless Sensor Network

Single Area Network has all the nodes spread within an area at randomly locations and each of the node will communicate with other node in the network using its own specific algorithm and there is no controlling authority. The Single Area Network is provided in the Fig3.



LEARNING ON TOOLS USED IN IOT DEVELOPMENT LIFE CYCLE

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Learning on Tools Used in IoT Development Life Cycle

Shilpa V, Vidya A, S N Chandrashekara

Abstract: Internet of thing is an entity of the physical or virtual object, which is able to identified as well as integrated into communication system. Managing the Internet of Things is called as Web of Things. The IoT gadgets are rooted with sensors, gateways, Internet connectivity and cloud. Also using these gadgets we can converse with other devices through Internet for secured communication. Growth of IoT can be seen extremely fast in our present life. It is acknowledged that by 2020 thousands of billions of objects will be deployed globally. We trust to facilitate IoT as software-driven, therefore utility requirements resolve the modernization as well as improvement towards IoT. Primary domains identified are energy transportation, distribution, smart town, smart communication, smart domestic, atmosphere, supply chain, as well as fitness care. This study presents open source tools used in IoT development life cycle. The expression open source was mainly associated to infrastructure software, where we can improve the code re-usability rather than the implementation using web of objects.

Keywords : AMQP, CoAP, IoT, JSON, Node-RED, VSCP

I. INTRODUCTION

IoT is growing rapidly in everyday at a rate that is extremely quick. This brings the revise of IoT as well as its associated prospect incredibly essential. This study presents a developer to utilize the open tools for all IoT services. The word open source is associated with multiple packages in the software, that presents the original source object code. In general open source tools can be accessed from the developers till the end users to examine, utilization as well as change or growth. The development towards the Web of Things is mainly supported based on the improvement that are continuous in the area of microelectronics, IT Infrastructure. The modern days IoT application layer as shown in Fig. 1 is named as connectivity terminologies. The word connectivity mainly concentrates on Web of Things with different building blocks such as Gateway WoT, Note WoT, LAN and WAN WoT and many more. It has assistance to create more requests that are riveting as well as ranging from machine-driven entities to information analyzers.

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Web of Things consists of interconnected gadgets similar to smart home appliances, equipment, wheels. The user experience depends on the virtual structure as well as its specifications [1] [2] [3].

II. UTENSILS FOR DEVELOPING INTERNET OF THINGS

Implementing an IoT typically calls for the mutual supervision of an actuator and an endpoint. The mechanism that monitors the connected device is mainly probing for a particular assessment that energizes the end point into movement. This can be a linked home surroundings gadget that permits the end user to reveal the high temperature of the residence and alter the thermostat settings slightly, or else it can be a security gadget that tracks moves inside a structure and alert designated customers for changes.

IoT LAN	Local, Short range comm., may or may not connect to internet, building or organization wide
IoT WAN	Connection of various network segments, organizationally and geographically wide, connects to the internet
IoT Node	Connect to other nodes inside a LAN via the IoT LAN, may be sometimes connect to the internet through a WAN directly
IoT Gateway	A router connecting the IoT LAN to a WAN to the internet, can implement several LAN and WAN. Forwards packets between LAN and WAN to the IP Layer
IoT Proxy	Performs active application layer functions between IoT nodes and other entities

Fig. 1. Modern Days IoT Application Layer [1].
 Developing applications for linked gadgets requires the following:

- Endpoint authentication,
- Session advent or creating a session,
- Destructing a session and logout from a session,
- Individual device statistics plan info,
- Individual person billing info as wished,
- Individual device details,
- User latest API activity,
- Tool claiming and activation,
- Incoming and outgoing SMS control,
- Device ordering.

IoT solutions discriminates mainstream tools provided by the company and it provides the principal edge to the IoT gadgets. There are companies that still function largely far away from the tech segment. They will also notice profit based on some market terms and conditions.

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VERIFICATION OF OVER-SPEED AND BURST MARGIN LIMITS IN AERO ENGINE ROTOR COUPLING ALONG WITH ESTIMATION OF LOW CYCLE FATIGUE LIFE

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Verification of Over-Speed and Burst Margin Limits Inaero Engine Rotor Coupling Along with Estimation of Low Cycle Fatigue Life

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Abstract

Turbine of an aero engine is considered as a key knowledge for development in overall engine performance. High performance turbines with augmented operational temperature require sophisticated design concepts. Weight reduction, increased strength and stiffness are the major requirements for highly stressed turbine disc in forthcoming aircraft engines. A major challenge during the design process of a modern low weight turbine disc is to find rotor disc geometries that meet both, static and fatigue requirement for both mechanical and thermal loads. The important functions of flexible coupling in turbomachines are, transmit mechanical power from one shaft to another with constant velocity, reimburse for mis-alignment without affecting structural integrity, without generating excessive thrust on either shaft for axial movement with minimum power loss. Aero engine rotor burst evaluation is one of the most important problems to be taken care off, whenever it comes to designing a turbo machinery disc. The consequences of a failure can be intense, since the disc fragments into multiple pieces and they are hurled away in all the possible direction at high speeds. In present work evaluation of safety limits and low-cycle fatigue (LCF) life estimation of an aero engine flange coupled disc through classical methods. By blending the terminologies with simulation engineering to arrive at a probable interpretation of number of duty cycles is carried out. The methodology compares the fatigue parameters involved in evaluation of disc life at off-design condition through sensitivity analysis. The design tool closely connects the flight certification regulating agencies for safety in air transportation vehicles. The off-design speed regulations through API and MIL handbook for material specification are considered to carry out finite element analysis.

Keywords: Flexible couplings, rotor burst, low-cycle fatigue, API & MIL handbook, finite element analysis

INTRODUCTION

The functional necessities and features of flexing coupling is to transmit rated torque without undergoing buckling, permanent deformation i.e. to possess with high torsional rigidity. However, under conditions of misalignment, flexing coupling element must have necessary flexibility to accommodate these situations without inducing excessive force and moment on shoulder shaft, bearing and bolts. Misalignment is compensated using laminated disc sets. Both of the requirements should be achieved by maintaining stress levels which are safely in the range of fatigue limit of flexing material. Metal-flexing

coupling is identified to show irregular large-amplitude vibrations in axial direction when excited at natural frequency of coupling.

Considering various loads acting upon the disc and variation of the loads with respect to time are the factors that add to the complexity of turbine disc design. Weight of disc plays a vital role in improving efficiency of the gas turbine[1]. Hence, allows component to operate under plastic zone assuring the safety of the component with design limits. In present work an attempt is made to understand design criteria's used for the design of gas turbine disc running at speed of 12000 RPM and operating at a temperature of 500°C. The finite element analyses were carried out to check the mechanical and structural integrity of the disc in a systematic order using the commercially validated FE package software. This includes,

- A sensitivity study for material model and its behaviour at in-service condition.
- 3-D analysis for estimation of over-speed margin evaluation with safety factor
- Estimation of over-speed margin in rotating aero rotor disc as per international authorities for integrity, blending the classical approach with FEA
- Application of 3-D elasto-plastic strain to conventional equations to arrive at fatigue life of disc; Coffin-Manson method

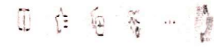
DESIGN CONSTRAINTS

The major loads acting on turbine blades are, centrifugal and thermo-mechanical loads. Thermal load is dominated by centrifugal loads for every cycle; Hence, importance is given for mechanical loads. In a bladed disk assembly, the disk happens to be the stronger section compared to disk. Replacing blade under failure is cost effective than replacing disks. During operating at design speed and over-speed circumstances, the average stresses obtained at cross sectional areas has to be well within allowable design limits as per design rule for both blade and disk. To sidestep all these complexities an integrated bladed rotor coupled assembly is considered for analysis. The constraints for present analysis is sequenced as follows

1. Design Parameters
2. Behavior constraints

STRENGTH CHARACTERISTICS OF HIGH PERFORMANCE CONCRETE USING BAGASSE ASH AND SLAG SAND

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Strength Characteristics of High Performance Concrete using Bagasse Ash and Slag Sand

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ABSTRACT

Today the high demand in industry is fast construction owing to the properties of strength and high durability. Over the years' concrete has seen progressive development with respect to high performance. High performance concrete (HPC) due to its own property is been largely used for construction of global infrastructure such as bridges, dams, roads etc. The main aspect of the work is to check the durability and strength of HPC. In this study, an investigation is performed to develop high performance concrete using waste materials like Bagasse ash and slag sand - from different industries - with different percentage. Cement is partially replaced by Bagasse ash and M sand by slag sand with varied concentration. Concentration of Bagasse ash replaced in cement are 0%, 8%, 12%, 16%, and 20%, as for Manufactured sand the replaced percentage of slag sand is 0%, 15%, 30%, 45% and 60%. The physical test of constitutes used in HPC has been carried out. The strength characteristics such as compression, tension and flexure are conducted for the curing period of 28 days. The result shows that, including Bagasse ash and slag in concrete increases the compressive strength up to a percentage concentration of 8% Bagasse ash and 15% slag sand, any further increase in the concentration of Bagasse ash and slag sand would decrease the overall strength of concrete.

Key words: Bagasse ash; slag sand; high performance concrete compression; flexure; tension.

1. INTRODUCTION

According to American Concrete Institute, Concrete needs special combination of uniformity and performance requirements that cannot be achieved using regular constituents and traditional mixing, placing, and curing practices. High performance concrete (HPC) is intended to design and perform higher than nominal concrete in terms of its durability and strength [1, 2]. The proportions of High-Performance Concrete (HPC) mixtures are designed and engineered towards providing high strength and durability, although composing of primarily the same materials as conventional concrete mixtures, necessary for the structural and environmental

requirements of the project. The approximate compressive strength of High-strength concrete is more than or equal to 55 MPa. This value of 55 MPa is chosen, as it would require special care for production and testing of the concrete and this defined high strength value would require special structural design [3, 4, 5]. Contents of High-performance concrete would include one or more of cementitious materials namely Silica fume, ground granulated blast furnace slag or fly ash & sometimes a superplasticizer. The term 'high performance' is somewhat pretentious because the basic feature of this concrete is that it's constituents and quantities are carefully chosen so as to have specifically appropriate properties that are intended use of structure viz high strength and low penetrability [6, 7, 8].

Hence, High-performance concrete (HPC) does not behaves differently when compared to nominal concrete as the composition of nominal and HPC are same [9, 10, 11]. The workability qualities, strength and durability are enhanced to a very high extent due to the use some admixtures and minerals viz Silica fume and Superplasticizer.

2. CHARACTERIZATION OF MATERIALS

The property of the materials is obtained from the experimental tests carried out according to IS codes for cement, bagasse ash, slag sand, manufactured sand (M-sand), 20mm and 12 mm aggregates.

A. Cement

Birla super 53 grade of OPC is used as referred in the code IS 12269-1987 the terms of tests as per IS-4031 part 11-1988. The tests are carried out and the properties of the cement are obtained.

3. BAGASSE ASH

Bagasse ash is used as replacement material for the cement. Bagasse ash is procured from the sugar factory in K.M Doati

ANALYTICAL AND EXPERIMENTAL STUDY OF FLEXURAL BEHAVIOUR OF SLAG SAND REINFORCED CONCRETE BEAMS WITH VARIOUS DUCT OPENINGS

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Analytical and Experimental Study of Flexural Behaviour of Slag Sand Reinforced Concrete Beams with Various Duct Openings

Naveen Kumar B M, Revanasiddappa Madihalli, Murali C T, Rudraswamy M P

Abstract: The provision of transverse openings in floor beams to facilitate the passage of utility pipes and service ducts results not only in a more systematic layout of pipes and ducts, it also translates into substantial economic savings, in the construction of a multi-storey building. Along with opening, the partial replacement of steel slag sand with crushed stone is done which further reduces the cost of the beams. In order to obtain the optimum level of replacement, steel slag sand is varied from 0-100% and tested under compressive strength for maximum strength. With help of ANSYS software, various shapes of openings, keeping equivalent area of cross section such as circular, rounded rectangular and rounded square, provided at critical zone are modelled and analysed in order to obtain the optimum shape of the openings in beams. To reduce stress concentration at corners of the openings, special reinforcements are provided as per ACI specification. With that optimum shape experimental work is carried out. Where 8 beam were casted of size 2000*450*230mm and tested under loading frame with two pint loading and simply supported condition. The results obtained such as deflection, initial cracks, and ultimate failure load were compared with the beams without openings, with openings using steel slag sand and without using steel slag sand. Also comparison of analytical results with that of experimental results was carried out.

Key words: Compressive Strength, ANSYS, Openings.

I. INTRODUCTION

A. General

In the present scenario, we know that the second widely utilized material is cement next to water, hence it has a very adverse impact on the present environment. Engineers and scientists are trying all the possible alternatives for replacement of building material, which are eco-friendly and emphasizing on the use of reprocessed and reutilized metallurgical waste.

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such that accumulation of industrial waste like iron and steel slag can be minimized and put into practice to produce concrete by making use of it efficiently to its full extent. Slag sand is solid waste disposed in huge amount by iron and steel industry across the world.

It possess similar property as that of river sand, hence can be used as replacement for fine aggregate or coarse aggregate depending on the application of the concrete. Steel slag sand can also be used with cement as active admixture to order to enhance the concrete properties. These supplementary cementitious materials greatly reduce the impact on natural resources along with decrease of CO₂ emissions. Due to fast economic growth there is an urgent need to pay attention towards alternatives and research work needs to be carried out towards it. In the current study, the usefulness of slag sand is studied in reinforced concrete beams with different duct opening. Experimental and analytical work is carried out to understand the behaviour of the RC beams. For the conveyance of pipes and ducts for various purposes such as air conditioner, sewage pipe and water supply system etc. are passed through the transverse opening in the floor beams. When such type of design is adopted, it reduces the height of the structures and it tends to a most economical design. Whenever an opening is provided in beams, it possess problems pertaining to stress concentration at the corners of the opening, deformation and excessive deflection under service load, hence a special consideration on design of the beam around the opening. According to ACI code is carried out, in order to counteract the negative effects of the premature failure of the beams due to Vierendeel Truss Action. When diagonal reinforcements are provided it improves the load carrying capacity of the beam. The aim of this study is to investigate the behaviour of steel slag sand reinforced concrete beams with various shapes of duct openings.

B. Steel Slag Sand

The slag sand is a secondary product obtained from steel and iron manufacturing industry by Basic Oxygen Furnace (BOF) & Electrical Arc Furnace (EAF). Nearly 110-180kg of steel slag is produced from every 1 ton of steel produced. The components of steel slag include MgO, SiO₂, CaO, Al₂O₃ & Fe.

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