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Tailoring of optical band gap by varying Zn content in $Cd_{1-x}Zn_xS$ thin films prepared by spray pyrolysis method

AIP Conference Proceedings **1728**, 020624 (2016); https://doi.org/10.1063/1.4946675

Vipin Kumar[1, a)], D. K. Sharma[1], Sonalika Agrawal[1], Kapil K. Sharma[1], D. K. Dwivedi[2], *and* M. K. Bansal[3]

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ABSTRACT

$Cd_{1-X}Zn_XS$ thin films (X = 0.2, 0.4, 0.6, 0.8) have been grown on glass substrate by spray pyrolysis technique using equimolar concentration aqueous solution of cadmium chloride, zinc acetate and thiourea. Prepared thin films have been characterized by UV-VIS spectrophotometer. The optical band gap of the films has been studied by transmission spectra in wavelength range 325-600nm. It has been observed that optical band gap increases with increasing zinc concentration. The optical band gap of these thin films varies from 2.59 to 3.20eV with increasing Zn content.

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Thermal annealing induced structural and optical properties of $Se_{72}Te_{25}In_3$ thin films

AIP Conference Proceedings **1728**, 020322 (2016); https://doi.org/10.1063/1.4946373

H. P. Pathak[1], Nitesh Shukla[2], Vipin Kumar[2], *and* D. K. Dwivedi[1, *]

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ABSTRACT

PDF

Thin films of a- $Se_{72}Te_{25}In_3$ were prepared by vacuum evaporation technique in a base pressure of 10^{-6} Torr on to well cleaned glass substrate. a-$Se_{72}Te_{25}In_3$ thin films were annealed at different temperatures below their crystallization temperatures for 2h. The structural analysis of the films has been investigated using X-ray diffraction technique. The optical absorption spectra of these films were measured in the wavelength range 400-1100 nm in order to derive the absorption coefficient of these films. The optical band gap of as prepared and annealed films as a function of photon energy has been studied. It has been found that the optical band gap decreases with increasing annealing temperatures in the present system.

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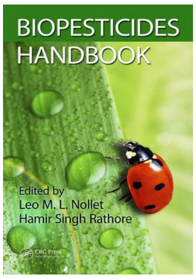

Biopesticides Handbook

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ABSTRACT

TABLE OF CONTENTS

Design issues for wireless sensor networks and smart humidity sensors for precision agriculture: A review

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Syed Akhtar Imam ; Amit Choudhary ; Vibhav Kumar Sachan **All Authors**

Abstract

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Abstract: Precision agriculture is a process in which information and technology is used for collection of high resolution spatio-temporal data regarding atmospheric and soil condi... **View more**

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Abstract:
Precision agriculture is a process in which information and technology is used for collection of high resolution spatio-temporal data regarding atmospheric and soil conditions from farm land. With the help of farm land data and an appropriate crop-growth model, a decision support system regulates the agricultural needs precisely in order to gain maximum benefits for farmer. Application of Wireless Sensor Networks (WSN) provides a low cost and easy to implement solution for automatic data collection from farmlands. Various design issues for WSN in context of precision agriculture have been reviewed in this paper. Humidity (RH) sensors play a crucial role for WSN for precision agriculture applications. This paper also reviews various requirements of Humidity sensors characteristics in context of WSN application for precision agriculture. In the later section of the paper, in depth comparative review of recent research work done in field of design and performance modeling of humidity sensor has been given.

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Contents

I Introduction

Even after spending a lot of money and human resources by central and state governments for the agricultural growth like subsidies on fertilizers, low interest agricultural loans, setting up rural branches of national banks, a shortage of soil testing labs is observed in most of the states of the country. [1] Due to which farmers do not have a tendency to test their soil in order to increase crop yields. As a result, farmers remain unaware of atmospheric conditions like Relative Humidity (RH) of the air, Temperature and soil characteristics like soil type, soil porosity and pesticide levels etc. [2] Due to which they apply more or less irrigation/fertilization as compared to the required precise quantities for a particular crop under given soil and environment conditions. If fertilization is applied in less quantity, it severely affect crop yield leading to financial loss of farmers. Over fertilization contaminates ground water leading to the problem of mass cancer as being faced by many regions of Punjab state. [3] If soil samples are taken to a Lab testing facility by some farmers, this sample cannot represent soil of large farm lands of hundreds of hectare field. Also the soil properties change from time to time. Thus soil data experimentally taken at one time do not remain valid for large crop seasons. For precise application of agricultural inputs, accurate spatial-temporal data from farm lands regarding soil and atmospheric conditions is required at regular intervals. [4] Based on such information, required crop inputs like irrigation of pesticides can be applied in precise quantity. The process of using information and technology for precise regulation of agricultural needs in order to gain maximum benefits for farmer has been termed as precision agriculture.

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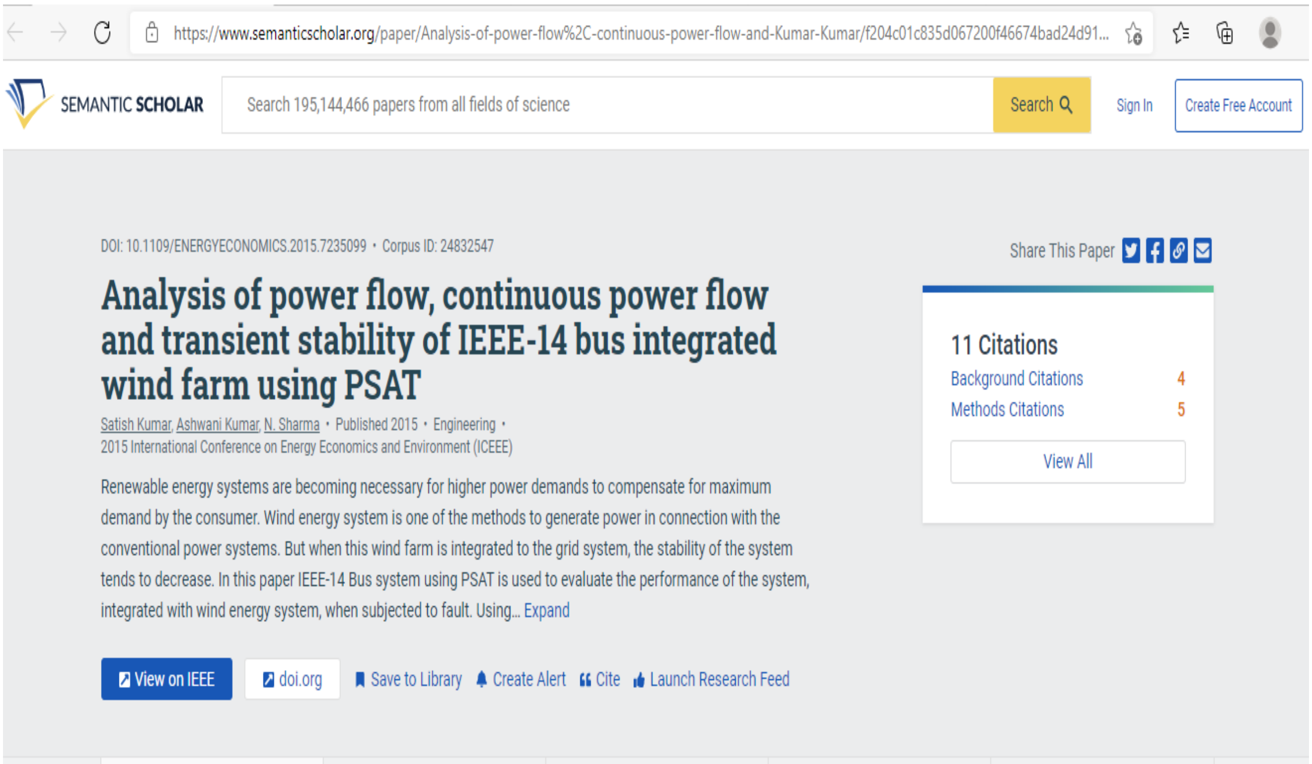

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Satish Kumar, Ashwani Kumar, N. Sharma • Published 2015 • Engineering •
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Renewable energy systems are becoming necessary for higher power demands to compensate for maximum demand by the consumer. Wind energy system is one of the methods to generate power in connection with the conventional power systems. But when this wind farm is integrated to the grid system, the stability of the system tends to decrease. In this paper IEEE-14 Bus system using PSAT is used to evaluate the performance of the system, integrated with wind energy system, when subjected to fault. Using... Expand

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Microstrip Patch Antenna Array with Metamaterial Ground Plane for Wi-MAX Applications

Authors | Authors and affiliations

Chirag Arora, Shyam S. Pattnaik, R. N. Baral

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Abstract

In this paper a microstrip patch antenna array, loaded with a pair of Split Ring Resonators (SRR), has been presented. This antenna is designed for IEEE 802.16a 5.8 GHz Wi-MAX applications. A pair of SRR has been etched on the ground plane of the antenna. This loading of https://link.springer.com/chapter/10.1007/978-981-10-5427-3_26

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Blood Pressure Control During Anaesthesia With and Without Transport Delay

Authors Authors and affiliations

Varun Gupta , Abhas Kanungo, Piyush Chandra Ojha, Pankaj Kumar

Conference paper
First Online: 22 July 2017

Part of the Communications in Computer and Information Science book series (CCIS, volume 721)

Abstract

Regular monitoring of the anaesthetic drug dosage during a surgery is required to avoid the patient's inter operative awareness due to inadequate levels of anaesthesia. The traditional methods of assessing the anaesthetic depth levels such as heart rate, blood pressure, pupil size,

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Respiratory signal analysis using PCA, FFT and ARTFA

Publisher: IEEE Cite This PDF

Varun Gupta ; Monika Mittal All Authors

Abstract

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Abstract:
Sinus patients, both humans and animals, are increasing day by day in the world. That's why today signal analysis has been the need to know the diseases in the patient. Biomedical signal processing (BSP) has great importance in the life of every human and animal. Without BSP signals cannot be analysed, resulting in failure of disease acknowledgment. In this paper respiratory signals of Sinus and Normal Person has been analysed using Principal Component Analysis (PCA), Fast Fourier Transform (FFT) and Auto-Regressive Time-Frequency Analysis (ARTFA). PCA is used where dimension reduction is required. It has found many applications in BSP. ARTFA allows us to follow the changes in frequencies involved in the signal through time. For this, frequency changes in time are required to be observed. FFT examines the signal in frequency domain and calculates the spectral function (SF). In this paper, the variance of First Principal Component and Second Principal Component have been calculated for Sinus and Normal Person and these values are 86.94%, 13.05% and 92.733%, 7.266% respectively.

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LQR and PID Design Technique for an Electric Furnace Temperature Control System

Proceeding of International Conference on Intelligent Communication, Control and Devices pp 561-567 | Cite as

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Conference paper
First Online: 18 September 2016

Part of the Advances in Intelligent Systems and Computing book series (AISC, volume 479)

Abstract

This paper presents a Linear Quadratic Regulator Controller design for Temperature Control of an Electric Furnace System using MATLAB. Also, Proportional-Integral-Derivative (PID) Controller is designed for control of an Electric Furnace. The three PID parameters K_p, K_i, and K_d are obtained using two tuning methods, Ziegler Nicholas and Tyreus Luyben. Performance of the system using LQR and PID (using Ziegler Nicholas and Tyreus Luyben) control techniques for an Electric Furnace Temperature System is compared by analyzing the Time Response of the system. The result of simulation shows that LQR technique gives better performance for the given system.

Keywords

LQR PID controller Ziegler Nicholas tuning Tyreus Luyben tuning Electric furnace

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Abstract

Application software Metric Software development life cycle

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Volume 57, 2015, Pages 1332-1341

Optimization of Value of Parameters in Ad-hoc on Demand Multipath Distance Vector Routing Using Teaching-Learning Based Optimization

A.K.Giri [a, b], D.K.Lobiyal [a], C.P.Katti [a]

https://doi.org/10.1016/j.procs.2015.07.445

Abstract

The performance of Vehicular ad-hoc network (VANET) depends on many factors. One of the factors is routing protocol and the performance of routing protocol in given scenario depends on the value of parameters used in. The combinations of such values are very large. Therefore, we have used Teaching-Learning Based Optimization (TLBO) technique to nd optimal value of parameters for Ad-hoc On Demand Multipath Distance Vector (AOMDV) in given real scenario. The Experimental results show drastic improvements in Average End-to-End delay (90.50% drop), Network Routing Load (41.68% drop) and Packet Delivery Ratio (0.39% rise) using value of parameters obtained through TLBO.

Previous Next

Keywords

AOMDV; TLBO; VANET

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Approach for Information Retrieval by Using Self-Organizing Map and Crisp Set

Speech and Language Processing for Human-Machine Communications pp 51-56 | Cite as

Conference paper

First Online: 16 November 2017

Part of the Advances in Intelligent Systems and Computing book series (AISC, volume 664)

Abstract

Nowadays, mostly users want to search anything they have done by Web search. For finding the concerned information with the reduced retrieval time they go through the search engine. Finding the relevant information with the help of mapped area affects the supervised and unsupervised learning method and works on the designing part of the information retrieval by using SOM and crisp set (CrispSOM), as well as reduces the retrieval time and collects the scattered information using self-organizing map and crisp set. The innovative idea of this paper is to evaluate the application of self-organizing maps (SOM) with the help of crisp value for finding the relevant information in lesser time as compared to other information retrieval system (IRS).

Keywords

Database searching   Information retrieval   Self-organizing map   Crisp set

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Automatic classification of movie trailers using data mining techniques: A review

Publisher: IEEE Cite This PDF

Prashant G. Shambharkar ; M N Doja **All Authors**

Abstract: Nowadays huge amount of data is generated through various activities. To manage the data in proper format and the way it is to be maintained. There are so many ways to ma... **View more**

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Abstract:

Nowadays huge amount of data is generated through various activities. To manage the data in proper format and the way it is to be maintained. There are so many ways to maintain the data. Classification of data is done so as to identify and put that data in different classes. It is nothing but to group that data in different classes and retrieve as and when it is required with ease. The classification of data is to make the user aware the class of that data on the basis of certain attributes. In this paper we basically focus on the movie trailers using different data mining approaches to classify the videos. The amount of video that a viewer has to choose from is now so large that it is infeasible for a human to go through it all to find movie of interest. Here various methods and techniques are discussed for classification of video and movie trailers.

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Contents

Introduction

As the huge amount of movie data is generated, user needs some specialized tools to retrieve that data and use it. Users can use their choices to choose a movie within particular categories of genre. Mehmet et.al [1] gave method for video categorization of movie based on genre classification as shown in the Figure 1. In order to get improved and the best possible results, authors use low level visual feature cues and then incorporating the higher level semantic understanding of feature films. The main categories are Action, Comedy, Drama, and Horror. Also for

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Web service discovery and integration with QOS parameter using SOA based repository

Publisher: IEEE

Vinay Kumar Tiwari ; Amit Kumar Gautam ; Saurabh Diwaker **All Authors**

Abstract: Any Organization needs to manage and analyze its information. The source of this information may not be the same, organizations use different information system to suppor... **View more**

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Abstract:

Any Organization needs to manage and analyze its information. The source of this information may not be the same, organizations use different information system to support their different area of work. Different departments of organization use their specific information system and platform to maintain their own data. But some information is needed by different departments for co-ordination between these departments. The distributed Web Service is managed by registries is issue in the circumstances of a Web Services which is on distributed system. The recent registry is managed and offer for distributed service registries are explained. By this explanation, it was created that none of any given offer that the requirements of flexibility, availability and scalability is proved in terms of the management of the registries. Therefore, a QoS based registry is introduced in current paper. The system uses tmodel(technical model) for storing of the service registries. In this paper involves design and implementation of a UDDI with QoS parameter. It helps to find quality web services using SOAP (Simple Object Access Protocol) message. It serves two fold purposes; first to register quality web services. Second, find that service. A Software for the implementation of these aspects is contributed in this work.

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Contents

I. Introduction

All organization is interested to develop such an application architecture

- Web services are dynamic due to change in the user requirement.
- Web services are usually developed by different task and by different organization so they may be rely on different platform.

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Keywords

A tool to generate all DU paths automatically

Publisher: IEEE Cite This PDF

Sumit Kumar ; D K Yadav ; D A Khan ; Anurag Srivastava **All Authors**

Abstract: Software testing takes a considerable amount of time and resources spent on producing software. Software testing includes test data generation that is the process of iden... **View more**

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Abstract:

Software testing takes a considerable amount of time and resources spent on producing software. Software testing includes test data generation that is the process of identifying a set of program input data satisfying a given testing criterion. There has been active research to find out ways to reduce the cost of software testing. Increasing the degree of automation and the efficiency of software testing certainly can reduce the cost of

Contents

1. Introduction

Software testing is an activity which involves execution of the developed software with the intent of finding as many errors as possible [1] and checking the quality of the developed software. Software testing is one of the most significant phases of Software Development Life Cycle (SDLC). More than 50% of the cost incurred in the software development is devoted to testing processes of the software [2]. Manual testing is a labor extensive and time consuming process. Hence, it is required to automate testing processes to reduce time and cost involved in the software development. Software Testing can be broadly classified in two categories: (i) Static Testing, and (ii) Dynamic Testing. Static software testing techniques involves desk checking, code review; examine specification documents, design documents and source code of the software under test (SUT). In dynamic software testing, the SUT is executed on input test data and tested for its functionality (functional or black box testing) or for its structure (structural or white box testing) [4], [5].

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Keywords

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Geetika | Tanuj Nandan | Tripti Singh | Piyali Ghosh | Vibhuti Tripathi

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Modern business and production environments have become increasingly intertwined with the dynamics of global markets, and changes in these dynamics have a deep bearing on the way business is transacted. This creates the demand for interdisciplinary research and flexible systems, wherein thinkers and practitioners in the areas of management and technology are required to work hand-in-hand towards the evolution of a new paradigm, new theories, concepts and strategies of management for businesses to maintain their trajectories of growth.

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Abstract

The software industry is always striving for new technologies to improve the productivity of software and meet the requirement of improving the quality, flexibility, and scalability of systems. In the field of software engineering, the software development paradigm is shifting towards ever-increasing flexibility and quality of software products. A measure of the quality of software is therefore essential. Measurement methods must be changed to accommodate the new paradigm as traditional measurement methods are no longer suitable. This paper discusses the significant measurement factors as they relate to agent-based systems, and proposes some metrics suitable for use in agent-based systems.

Keywords

Agent-based system Measurement Metrics

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Influence of Elecro-thermo-convection on stability of binary fluid with reaction effect in a horizontal porous layer

Atul K. Srivastava[1], K.L.A. Khan[2], Sandeep Chhabra[3] and Naman Varshney[4]
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Abstract

In the present article, we illustrate the onset of electro-thermo convection of a binary fluid in a horizontal porous layer subject to fixed temperatures and chemical equilibrium on the bounding surfaces. The state of convection is considered, when the solubility of dissolved components depends on temperature. Linear stability analysis is used to investigate how the vertical electric field and dissolution or precipitation of the component affect the onset of convection. Darcy-Brinkman's law and Boussinesq approximation are employed with the equation of state taken to be linear with respect to temperature and concentration. We solved the problem analytically for a wide range $[0, 1000.0]$ of vertical AC electric field $\mathbf{R}_{ea}$, $[0, 5.0]$ of chemical reaction parameter, $[0.0125, 0.05]$ of Darcy number and $[20, 80]$ of salinty and show the effect on stability of the system. It is observed that vertical electric field and reactive term, both destabilize the system, whereas increasing salinty and Darcy term stabilize the system.

Keywords

Electro-thermo convection, Darcy-Brinkman model, binary fluid, ratio of viscosities.

I. Introduction

Onset of convection due to combined effects of an electric field and a thermal gradient concurrently applied to horizontal dielectric liquid layer guides a complex physical interactions in the flow and have received much attention in recent years ([1]-[3]). The research in this field considered reasonable interest due to the application of combined effects (such as potential technology, [4]-[8]) that generates electro-thermo convective instabilities in liquids that could be a promising way to increases the heat transfer by means of electrical forces. This kind of instability problem is called electro-thermo convection (ETC).

Assuming the variation in dielectric constant as a linear function of temperature, initially a study has been performed on electrohydrodynamic convection by Roberts [9]. An excellent reviews on the natural convection problem under alternating current (AC) or direct current (DC) electric field have been given by Jones [10] and Saville [11]. Problem related to ETC in a layer of porous medium under the influence of electric field is attracted interest because of its application in drying process (Yabe et al. [12] Lai and Lai [13]). Moreno et al. [14] have investigated transport-related effects of imposing AC currents over two-phase flows, oil and water, in porous rocks. Some interesting and important literatures indicating the work related ETC in porous layers are [15]-[18].

A obvious question arise that what will happen if we consider binary electric liquid in place of electric liquid? It is also matter of investigation that whether chemical reaction takes place or not.

As a consequence of above questions it is important to introduce the applications and literature survey for convection in binary liquid and reaction convection. In some geothermal situations (Dando et al. [19]), the amount of solute dissolved in fluid changes with changing temperature, pressure and the local rock chemistry. The solute may be in dissolved from or precipitated onto the porous matrix. Thermal convection extensively effects the exchange of dissolved species with the porous medium. It may be affected with the change in amount of minerals dissolved in fluid.

The growing volume of work related to convection of binary fluid in porous media is amply documented in the review work of Nield and Bejan [20]. Onset of thermo-solutal convection of a binary fluid in a horizontal porous layer subject to fixed temperatures and chemical equilibrium on the bounding surfaces is investigated by Pritchard and Richardson [21] and references given it. According to their study, reactive term may be stabilising or destabilising in this case. On the basis of Brinkman model, the onset of convection for binary fluid with a reaction term in a horizontal sparsely packed porous media has been investigated by [22]. They reported that the Darcy number destabilize the system in case of both stationary and oscillatory mode. Recently, Malashetty and Biradar [23] investigated analytically onset of reaction-convection in binary fluid horizontal anisotropic porous layers. They showed that the chemical reaction may be stabilizing or destabilizing the system.

In the present article, an attempt has been made to find out the answers of above mentioned questions by investigating the flow dynamics of convection reaction in binary fluid saturated porous medium under the influence of vertical AC electric field. The present paper is organized as follows. Mathematical modelling is presented in section 2. Section 3, is devoted to a brief presentation of linear stability analysis. We quantify the real impact of ETC on heat transfer in section 4. In section 5, we present conclusions of work.

II. Mathematical Formulation

We consider a dielectric binary fluid saturated sparsely packed horizontal porous layer of depth d, which is heated and salted from below, with a uniform vertical AC electric field applied across the porous layer as shown in Fig. 1.. The lower surface is grounded and the upper surface is kept at constant potential V_1. Cartesian co-ordinates have been taken with the origin at the bottom of the porous medium, and the z-axis is vertically upwards. The surfaces are extended infinitely in x and y directions and constant temperature gradient ΔT and salinity gradient ΔS are maintained across the porous layer. We are assuming that Chemical equilibrium is maintained at the impermeable boundaries. The governing equations for an incompressible dielectric binary fluid saturated porous layer under the Boussinesq approximation are given by

$$\nabla.\overrightarrow{q} = 0, \tag{1}$$

$$\frac{1}{\phi}\frac{\partial \overrightarrow{q}}{\partial t} + \frac{\nu}{K}\overrightarrow{q} = -\frac{1}{\rho_0}\nabla P + \frac{\rho}{\rho_0}\overrightarrow{g} + \tilde{\nu}\nabla^2\overrightarrow{q} + \frac{1}{\rho_0}\overrightarrow{f_e}, \tag{2}$$

Following Phillips [24], the transport of heat and solute is described by the advection-diffusion equations

$$(\rho c)_m \frac{\partial T}{\partial t} + (\rho c)_f (\overrightarrow{q}.\nabla)T = (\rho c)_m \nabla.(\kappa_T.\nabla T), \tag{3}$$

$$\phi\frac{\partial S}{\partial t} + (\overrightarrow{q}.\nabla)S = \phi\kappa_s\nabla^2 S + k(Seq(T) - S). \tag{4}$$

The relation among the reference density, temperature and salinity is given by

$$\rho = \rho_0\left[1 - \beta_T(T - T_0) + \beta_S(S - S_0)\right]. \tag{5}$$

Here, $\overrightarrow{q}$ the velocity vector, T the temperature, P the pressure, ρ the fluid density, ρ_0 the fluid density at basic temperature, K is the permeability tensor of porous medium, κ_T and κ_S are the effective thermal and solutal diffusivity respectively, $\nu = \frac{\mu}{\rho_0}$ kinematic viscosity, μ the fluid viscosity, $\tilde{\nu} = \frac{\tilde{\mu}}{\rho_0}$ the effective kinematic viscosity, $\tilde{\mu}$ the effective fluid viscosity, $\overrightarrow{g}$ the acceleration due to gravity, ϕ the porosity of the porous medium, $(\rho c)_m = (1-\phi)(\rho c)_s + \phi(\rho c)_f$ where (ρc) is volumetric heat capacity, c the specific heat and f, m and s represent properties of fluid, κ the lumped effective reaction, S is salinity, β_T and β_S the coefficient of thermal and solutal expansions respectively.

Following Pritchard and Richardson [21], we have considered the equilibrium solute concentration is a linear function of temperature i.e. $S_{eq}(T) = S_0 + \eta(T - T_0)$, where $\eta = \frac{S_l - S_u}{T_l - T_u} = \frac{\Delta S}{\Delta T}$. The value of η may be positive i.e. $\eta > 0$ (i.e. the solubility increases with temperature) or negative i.e. $\eta < 0$ (i.e. the solubility decreases with temperature). In the present manuscript, we assumed the case $\eta > 0$. $\overrightarrow{f_e}$ represents the electrical origin and preferred expression for it following Stratton ([25] and Landau and Lifshitz [26]) is

$$\overrightarrow{f_e} = \rho_e\overrightarrow{E} - \frac{1}{2}\overrightarrow{E}.\overrightarrow{E}\nabla\epsilon + \frac{1}{2}\nabla\left(\rho\frac{\partial\epsilon}{\partial\rho}\overrightarrow{E}.\overrightarrow{E}\right). \tag{6}$$

where, $\overrightarrow{E}$ is the electric field, ρ_e the free charge density and ϵ is the dielectric constant. Last electrostriction term in Eq. (6) can be grouped with pressure term of Eq. (2). Coulomb force due to a free charge is represents by the first term of right hand side of the Eq. (6). Second term depends on the term ϵ. We consider the same phenomena as by Shivkumara et al. [18].

Assuming that the free charge density is negligibly small, the relevant Maxwell equations are (Roberts [9])

$$\nabla.(\epsilon\overrightarrow{E}) = 0, \tag{7}$$

$$\nabla \times \overrightarrow{E} = 0. \tag{8}$$

In view of Eq. (8), $\overrightarrow{E}$ can be expressed as

$$\overrightarrow{E} = -\nabla V, \tag{9}$$

where, V is the electric potential. The dielectric constant is assumed to be a linear function of temperature of the form

$$\epsilon = \epsilon_0[1 - \gamma(T - T_0)]. \tag{10}$$

where, γ (> 0) is the thermal expansion coefficient of dielectric constant and is assumed to be small.

The basic state of the fluid is assumed to be quiescent, and is given by

$$T_b(z) = T_l - \Delta T\frac{z}{d} \text{ and } S_b(z) = S_l - \Delta S\frac{z}{d}. \tag{11}$$

$$\epsilon_b = \epsilon_0\left[1 - \gamma\left(T_b - T_0\right)\right], \tag{12}$$

$$\nabla.\left(\epsilon_b\overrightarrow{E}_b\right) = 0. \tag{13}$$

where b denotes the basic state. In the view of Eq. (12) and noting that $E_{bx} = E_{by} = 0$, it follows that

$$\epsilon_b E_{bz} = \epsilon_0 E_0 = \text{ constant (say)}. \tag{14}$$

Then we have

$$E_{bz} = \frac{E_0}{1 + \frac{\gamma\Delta T z}{d}}, \tag{15}$$

and

$$V_b(z) = -\frac{E_0 d}{\gamma\Delta T}\log.(1 + \gamma\Delta T z/d) \tag{16}$$

where

$$E_0 = -\frac{V_1\gamma\Delta T/d}{\log[1 + \gamma\Delta T]}. \tag{17}$$

is the value of the electric field at z=0.

In this case the basic state, $Seq(T_b) = S_b$. We mentioned that Seq is linear in T, this allow the existence of steady basic state in which the solute is everywhere in chemical equilibrium with the solid matrix and therefore the vertical flux of solute is constant in space.

On the basic state, we superpose small perturbations in the form

$$\begin{aligned} &q = q_b(z) + q', T = T_b(z) + T', S = S_b(z) + S', \\ &P = P_b(z) + P', \rho = \rho_b(z) + \rho', \overrightarrow{E} = \overrightarrow{E}_b(z) + \overrightarrow{E}, \\ &\overrightarrow{\epsilon} = \overrightarrow{\epsilon}_b(z) + \overrightarrow{\epsilon}. \end{aligned} \tag{18}$$

where prime indicates perturbation. Introducing Eq. (18) in Eqs. $(1) - (5)$, and using basic state equations describe above we obtained

$$\nabla.q' = 0, \tag{19}$$

$$\begin{aligned} \left(\frac{1}{\phi}\frac{\partial}{\partial t} + \frac{\nu}{K} - \tilde{\nu}\nabla^2\right)\nabla^2 w' &= \beta_T g\nabla_H^2 T' - \beta_S g\nabla_H^2 S' \\ &+\nabla_H^2\left[\frac{E_0\epsilon_0\gamma}{\rho_0}\left(\frac{-\Delta T}{d}\right)\left(\gamma E_0 T' - \frac{\partial V'}{\partial z}\right)\right], \end{aligned} \tag{20}$$

$$(\rho c)_m \frac{\partial T'}{\partial t} + (\rho c)_f((q'.\nabla)T' - w'\frac{\Delta T}{d}) = (\rho c)_m \nabla.(\kappa_T.\nabla T'), \tag{21}$$

$$\phi\frac{\partial S'}{\partial t} + (q'.\nabla)S' - w'\frac{\Delta S}{d} = \phi\kappa_S\nabla^2 S' + \kappa(Seq(T') - S'), \tag{22}$$

$$\nabla^2 V' = \gamma E_0 \frac{\partial T'}{\partial z}. \tag{23}$$

Non-dimensionalising the Eqs. (19) – (23) using following transformations

$$\begin{aligned}&(x,y,z)' = d(x,y,z)^*, t = \frac{d^2}{\kappa_T}t^*, T' = \triangle T T^*,\\ &S' = \triangle S S^*, (u,v,w)' = \phi\kappa_T(u,v,w)^*,\\ &V' = \gamma E_0 \delta T d V^*.\end{aligned} \tag{24}$$

we obtained the non-dimensional governing equations (after dropping the asterisks) as

$$\begin{aligned}&\left[\frac{1}{\mathrm{Pr}}\frac{\partial}{\partial t} + \mathrm{Da}^{-1} - \Lambda\nabla^2\right]\nabla^2 - \mathrm{R}_T\nabla_H^2 T + \mathrm{R}_S\nabla_H^2 S\\ &-\mathrm{R}_{ea}\nabla_H^2\left(T - \frac{\partial V}{\partial z}\right) = 0,\end{aligned} \tag{25}$$

$$\left(\frac{\partial}{\partial t} - \nabla^2\right)T + \lambda(q.\nabla)T - \lambda w = 0, \tag{26}$$

$$\frac{\partial S}{\partial t} + (q.\nabla)S - w = \frac{1}{\mathrm{Le}}\nabla^2 S + X(T - S), \tag{27}$$

$$\nabla^2 V - \frac{\partial T}{\partial z} = 0. \tag{28}$$

where the non-dimensional parameters are, $\mathrm{R}_T = \frac{\beta_T g \Delta T d^3}{\phi\nu\kappa_T}$, $\mathrm{R}_S = \frac{\beta_S g \Delta T d^3}{\phi\nu\kappa_T}$ and $\mathrm{R}_{ea} = \frac{E_0^2\gamma^2\epsilon_0 d^2(\Delta T)^2}{\phi\rho_0\kappa_T\nu}$ are the thermal, solutal and AC electric Rayleigh numbers respectively, $\Lambda = \frac{\tilde{\mu}}{\mu}$ is ratio of viscosities, $\mathrm{Da} = \frac{K}{d^2}$ is a Darcy number, $\mathrm{Pr} = \frac{K}{d^2}$ is Prandtl number, $\lambda = \frac{\epsilon(\rho c)_f}{(\rho c)_m}$ the normalized porosity parameter, $\mathrm{Le} = \frac{\kappa_T}{\kappa_S}$ is Lewis parameter, $\chi = \frac{\kappa d^2}{\phi\kappa_T}$ is the Damkohler number.

The boundaries of porous medium can be considered as free that is stress free boundary

$$w = \frac{\partial^2 w}{\partial z^2} = T = S = 0, \quad \text{z=0, 1}. \tag{29}$$

III. Linear Stability Analysis

In this section, carrying out the linear stability analysis, we use normal mode technique in which, normal mode solution is of the form

$$(w, T, S, V) = (W, \Theta, \Phi, \zeta)(z)\exp[i(lx + my) + \omega t], \tag{30}$$

where l and m are horizontal wave number and $\omega = \omega_r + i\omega_i$ is the growth rate which is a complex quantity.

Substituting Eq. (30) into the linearised form of Eqs. (25)-(28) we obtain

$$\begin{aligned}&\left[\frac{\omega}{\mathrm{Pr}} + \mathrm{Da}^{-1} - \Lambda\left(D^2 - a^2\right)\right]\left(D^2 - a^2\right)W + \mathrm{R}_T a^2\Theta\\ &-\mathrm{R}_S a^2\Phi + \mathrm{R}_{ea}a^2\left(\Theta - D\zeta\right) = 0,\end{aligned} \tag{31}$$

$$\left[\omega - \left(D^2 - a^2\right)\right]\Theta - \lambda\omega = 0, \tag{32}$$

$$\left[\omega - \frac{1}{Le}\left(D^2 - a^2\right) + \chi\right]\Phi - \chi\Theta - W = 0, \tag{33}$$

$$\left(D^2 - a^2\right)\zeta - D\Theta = 0. \tag{34}$$

where $D = d/dz$ and $a^2 = l^2 + m^2$, where a is the wave number. The boundary conditions (29) is now

$$W = D^2 W = \Theta = \Phi = 0. \tag{35}$$

Eqs. (31)-(34) with chosen boundary conditions is a eigenvalue problem for R_T and a.

We assume the solutions of (31)-(34) satisfying the boundary conditions (35) take the form

$$\begin{aligned}&W = A_1\sin\pi z,\ \Theta = A_2\sin\pi z,\ \Phi = A_3\sin\pi z,\\ &\zeta = A_4\cos\pi z.\end{aligned} \tag{36}$$

Substituting (36) into Eqs. (31)-(34), we obtain a matrix equation

$$\begin{bmatrix} \left(\frac{\omega}{\mathrm{Pr}} + \mathrm{Da}^{-1} + \Lambda\delta^2\right)\delta^2 & -\left(\mathrm{R}_T + \mathrm{R}_{ea}\right)a^2 & \mathrm{R}_S a^2 & 0\\ -\lambda & \omega + \delta^2 & 0 & 0\\ -1 & -\chi & \omega + \frac{\delta^2}{\mathrm{Le}} + \chi & 0\\ 0 & \pi & 0 & \end{bmatrix}\begin{bmatrix}A_1\\A_2\\A_3\\A_4\end{bmatrix} = \begin{bmatrix}0\\0\\0\\0\end{bmatrix} \tag{37}$$

where $\delta^2 = a^2 + \pi^2$.

For non-trivial solution of A_1, A_2, A_3 and A_4, we need to make the determinant of the above matrix as zero. Following the same procedure adopted by Srivastava et al. [27], we obtain

$$\begin{aligned}\mathrm{R}_T = &\frac{1}{a^2\lambda\delta^2\left(\omega + \frac{\delta^2}{Le} + \chi\right)}[\left(\frac{\omega}{\mathrm{Pr}} + \mathrm{Da}^{-1} + \Lambda\delta^2\right)\left(\omega + \delta^2\right)\\ &\left(\omega + \frac{\delta^2}{Le} + \chi\right)\delta^4 + \mathrm{R}_S a^2\delta^2\left(\lambda\chi + \omega + \delta^2\right)\\ &-\mathrm{R}_{ea}a^4\lambda\left(\omega + \frac{\delta^2}{Le} + \chi\right)].\end{aligned} \tag{38}$$

1) Stationary state: For the direct bifurcation (i.e., steady onset), we have $\omega = 0$ at the margin of stability. Then, the Rayleigh number at which marginally stable steady mode exists, becomes

$$\mathrm{R}_T^{st} = \frac{\left(\mathrm{Da}^{-1} + \Lambda\delta^2\right)\delta^4}{a^2\lambda} + \mathrm{R}_S\mathrm{Le}\frac{\left(\lambda\chi + \delta^2\right)}{\lambda\left(\delta^2 + Le\chi\right)} - \mathrm{R}_{ea}\frac{a^2}{\delta^2}. \tag{39}$$

In the absence of electric field $(R_{ea} = 0)$ and double diffusive convection $(R_S = 0)$ the Eq. (39) reduces to

$$\mathrm{R}_T^{st} = \frac{\left(\mathrm{Da}^{-1} + \Lambda\delta^2\right)\delta^4}{a^2\lambda}. \tag{40}$$

This is well known result for Brinkman porous media.

When $\mathrm{Da} \longrightarrow \infty$, R_S, $\lambda = 1$ and $\Gamma = 1$ then Eq. (39) reduces to

$$\mathrm{R}_T^{st} = \frac{\delta^6}{a^2} - \mathrm{R}_{ea}\frac{a^2}{\delta^2}. \tag{41}$$

which gives the result of Roberts [9].

2) Oscillatory state: The growth rate σ is in general a complex quantity such that $\omega = \omega_r + i\omega_i$. The system with $\omega_r < 0$ is always stable, while for $\omega_r > 0$ it will become unstable. For neutral stability state $\sigma_r = 0$. We put $\omega = i\omega_i$ (ω is real) in Eq. (38) and obtain

$$\mathrm{R}_T = \frac{\left(\frac{\omega}{Pr} + Da^{-1} + \Lambda\delta^2\right)\left(\omega + \delta^2\right)\delta^2}{a^2\lambda} + \frac{\mathrm{R}_S Le\left(\lambda\chi + \delta^2 + \omega\right)}{\lambda\left(\delta^2 + \chi Le + \omega Le\right)} - \mathrm{R}_{ea}\frac{a^2}{\delta^2}. \quad (42)$$

It is clear from the Eq. (42) that oscillatory convection does not depends on AC electric field parameter that is on R_{ea}, so it is not reasonable to talk about over-stability here.

IV. Results and Discussions

This section is organized in some parts to provide full understanding of stabilities characteristics for ETC in binary fluid-saturated porous medium. A rigorous stability analysis has been performed here to answer the question of condition for the occurrence of the maximum stability. Since there are many controlling parameters in the present problem, here we carry out a parametric study to isolate factors that are responsible for the instabilities of electro-thermo convection in dielectric binary liquid in porous layers.

Effect of AC electric Rayleigh number: In this subsection, we illustrates the influence of R_{ea} in $\mathrm{R}_T - a$ plane in the form of neutral stability curves. Figs. 2(a) and (b) show the effect of R_{ea} on stability of system for different value of Λ when other parameters are fixed. The critical values of Rayleigh number, R_{Tc}= $5831.1996 > 5388.4674$ for same values of viscosities that is $\Lambda = 1.0$ and different values of $\mathrm{R}_{ea} = 0, 500.0, 1000.0$, when other parameters are fixed. However, $\mathrm{R}_{Tc} = 5388.4674 > 8848.4039$ for two values of Λ that is $\Lambda = 1.0$, (viscosities are same) and $\Lambda = 3.0$, (viscosities are different) respectively and for same value of $\mathrm{R}_{ea} = 1000.0$. Stability of the system decreases (as the critical value of R_{Tc} decreases) on increasing value of R_{ea} for both the value of $\Lambda = 1.0$ and 3.0 depicted in Figs. 2(a) and (b). It can also observed from the critical values of Rayleigh number that system is more stable for $\Lambda = 3.0$ in comparison of $\Lambda = 1.0$. To understand this phenomena, we recall the definition of R_{ea}, it is clear that increasing the value of R_{ea} means increasing the strength of electric field enhance the onset of convection. The physics to understand the effect of Λ is that as Λ increases, value of viscosity increases that causes problem in fluid flow.

Effect of reaction parameter: Figs. 3(a) and (b) show the effect of Damkohlar number on stability of system for different $\Lambda = 1.0$ and 3.0 when other parameters are fixed. Stability of the system decreases on increasing value of χ for both values of Λ shown in Figs. 3(a) and (b). This can be explained by giving a glance on the solute equation, in which additional reaction term is added. Since increasing the value of χ is basically increases chemical reaction rate, which in tern, changes the solute concentration of a displaced fluid particle to equilibrate quickly with that of the surrounding fluid. Effect of Λ is same as describe for Figs. 2(a) and (b).

Effect of Darcy number: Effect of Darcy number is depicted in Fig. 4. As Darcy number increases the permeability of the system increases that is fluid is free to move in all direction more freely, thus onset of convection delay. The results are same for both the conditions that is with and without electric field.

Effect of solutal Rayleigh number: This is illustrated by the Fig. 5, as R_S increases the the minimum value of critical Rayleigh number also increases thus stabilize the system. This is the result of enhancement of solutal buoyancy force in the system. The results are same for both the conditions that is with and without electric field.

V. Conclusion

We have to gain an understanding of instability of ETC with vertical AC electric field in a binary-fluid-saturated horizontal porous layer heated from below with chemical equilibrium on the boundaries. To this end, we adopted non-Darcy Brinkman model. By means of linear stability analysis we were able to extract detailed information of transition of basic flow of binary fluid through a porous medium under influence of vertical electric field. Normal mode technique is used to solve the set of linear ordinary differential equations. The main objective in this study was to investigate the role of vertical AC electric field ($\mathrm{R}_{ea} = 500.0$) on the stability of binary-fluid saturated porous layer in the presence of chemical reaction ($\chi = 2.0$). On the basis of above discussions, the following conclusions are drawn:

- Effect of increasing the value of R_{ea} and χ is found to enhance the onset of stationary convection.
- Effect of increasing the value of Λ, Da and R_S is found to delay the onset of stationary convection.
- From calculation it is concluded that the oscillatory convection does not depend on vertical AC electric field.

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Optimization of Welding Parameters for Weld Dilution in GMAW using Genetic Algorithm

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Abstract: *Hardfacing is a technique in which deposition of material on the surface of similar/dissimilar material is done to improve its wear resistant properties. The benefits also include the minimization of downtime needed to replace worn components and reduction of spare part inventory and finally saves money. So, it is essential to select welding process parameters carefully, to achieve a quality bead which is defect free. In order to achieve the above objective, a set of mathematical models has been developed for the prediction of weld bead dilution using 5-factor, 2 – levels Factorial design for 140MXC Nano structured wire with IS2062 substrate. The developed model was checked for its adequacy. The main and the interaction effects of the process parameters on weld bead dilution are presented in graphical form. Moreover, Genetic Algorithm computational model was used for the optimization of welding parameters to achieve desired optimum weld dilution.*

Keywords: *Harfacing, Gas Metal Arc Welding; Factorial Design Approach, Genetic Algorithm.*

1. INTRODUCTION

The welding process, due to its complexity, has relied on empirical and experimental data to determine its welding conditions. However, trial-and-error methods to determine optimal conditions incur considerable time and cost,as stated by Kim et al. [1]. In order to overcome these problems optimization of welding input parameters, for making high quality weldment can be envisaged as a vital area of research. Weld bead shape plays an important role in determining the quality and mechanical strength of the weldment. Weld bead geometry is dependent on number of input parameters such as wire feed rate, welding speed, voltage, nozzle to plate distance, gas flow rate etc. as stated by Kim et al. [2].To predict the effect of various welding parameters on weld bead geometry various researchers used variety of techniques. (Benyounis et al. [3]; Kannan and Yoganandh, [4]; Singla et al. [5];Sudhakaran et al.[6]).Statistical approach is one way to increase the amount of information-rich data gathered. Numerous studies validated that efficient use of statistical design of experiment techniques, works as an excellent tool for the development of a mathematical model for the prediction of weld bead geometry, (Murugan and Parmer[7], Subramaniam[8], Allen et al.[9], Kim et al.[10].

So, to achieve the above mentioned objective statistical designing technique was employed to depict weld bead geometry of surfaced steel. Experiments were conducted based on fractional factorial designing i.e., 2 level 5 factors. Process control variables considered were wire feed rate, welding speed, welding voltage, nozzle to plate distance and torch angle.

To ascertain the acceptability of weldment, control of dilution is very important in hardfacing, where low dilution is typically desirable. For the present research, it was planned to use GA computational technique for the optimization of welding parameters to minimize dilution, as it owns high reliability, robustness and accuracy, Palaniswamy et al. [12].

2. MATERIALS AND METHODS

2.1 MATERIALS

The experiments were carried out by the deposition of 140MXC Nano-structured wire of 1.6 mm diameter using Miller Migmatic 273 welding machine onIS2062 substrate. The chemical composition of substrate and filler wire are given in table 1. Shielding gas used was pure Argon with flow rate kept constant at 25 l/min. Bead- on – plate technique was used to make the weld runs.

TABLE 1: Chemical composition of base plate and filler wire

IS 2062								
Element	C	Si	Mn	S	P	Fe		
%	0.227	0.161	0.50	0.05	0.023	Balance		
TAFA 140MXC Nano-structured wire								
Element	Cr	C	Mo	B	W	Si	Nb	Fe
%	20.8	2.84	12.1	0.64	9.79	0.54	0.8	Balance

2.2 EXPERIMENTAL DESIGN

Factorial design can be written in the form of a design matrix where the rows correspond to different trials and the columns correspond to the levels of the process parameters. The design matrix developed to conduct the sixteen trials of 2^n fractional factorial design is given in table-2. To determine the two levels of each control variables, pilot study was carried out by varying the control variables in all possible combination. The experiments so carried, gave the limits, which is shown in table- 3.

Welding parameters were coded as (+1) and (-1), corresponding to the high and low levels for the ease of recording and processing of the data using equation (1).

$$X_j = (X_{jn}-X_{jo}) \;/ J_j \qquad (1)$$

Where, $X_j$is the coded value of the parameter, $X_{jn}$is the natural value of the parameter, X_{jo} is the natural value of the basic level, $J_j$is the variation interval and j is the number of parameter.

TABLE 2: Design matrix

Experiment No.	W 1	S 2	V 3	N 4	T 5= -(1234)
1	-1	-1	-1	-1	-1
2	1	-1	-1	-1	1
3	-1	1	-1	-1	1
4	1	1	-1	-1	-1
5	-1	-1	1	-1	1
6	1	-1	1	-1	-1
7	-1	1	1	-1	-1
8	1	1	1	-1	1
9	-1	-1	-1	1	1
10	1	-1	-1	1	-1
11	-1	1	-1	1	-1
12	1	1	-1	1	1
13	-1	-1	1	1	-1
14	1	-1	1	1	1
15	-1	1	1	1	1
16	1	1	1	1	-1

TABLE 3: Levels of the welding parameters

Parameters	Units	Symbols	Lower Limit -1	Upper Limit +1
WireFeed Rate	m/min	W	7.62	9.04
Welding Speed	cm/min	S	27	36
Voltage	Volts	V	26	32
Nozzle to Plate Distance	mm	N	15	20
Torch Angle	Degree	T	80	100

2.3 WELDING PROCEDURE AND DILUTION MEASUREMENT

Fromdesignof experiments, it was clear that 16 trials were needed toconduct the experiments, keeping the values set in the design matrix. The weld runs were then performed on each of these strips throughout the length of the strip using bead- on – plate technique.

To get the dimensions of the bead geometry all the samples were cut and scanned. The scanned images were then transferred to Corel Draw X5, using the ruler tool in the software. Calculated values of %dilution are tabulated in Table 4.

TABLE 4: %Dilution

Experiment No.	1	2	3	4	5	6	7	8
Dilution, %D	40.01	33.34	34.7	36.95	44.25	33.9	38.25	50.86
Experiment No.	9	10	11	12	13	14	15	16
Dilution, %D	24.5	39.61	32.6	42.29	52.56	41.6	53.46	36.69

3. SELECTION AND DEVELOPMENT OF MATHEMATICAL MODEL

The response function representing % dilution, can be represented as:

$$\%Dilution = f\,(W, S, V, N, T) \qquad (2)$$

Where, W, S, V, N and T represent the wire feed rate, welding speed, welding voltage, nozzle to plate distance and torch angle respectively.

The above expression, being a second degree response surface can be expressed as:

$$y = b_0+b_1W+b_2S+b_3V+b_4N+b_5T+ b_6\, WS+b_7\, WV+b_8\, WN+b_9\, WT+b_{10}\, SV+b_{11}\, SN+b_{12}\, ST+b_{13}\, VN+b_{14}\, VT+b_{15} \qquad (3)$$

Where, b_0, b_1,b_2, ……………$b_{15}$are the coefficients of the polynomial equation

The value of regression coefficients was calculated using equation 4,

$$bij = \frac{\sum_{i=1}^{M} X_{ji} Y_i}{M}, \; j = 0,1,2,3......,k \qquad (4)$$

Where, X_{ji} is the value of a parameter or interaction in coded form, Y_i is the average value of the response parameters, is the number of observations and k is the number of coefficients of the model. These models for predicting different responses mentioned above are given below:

%D= 39.72 - 0.32W + 1.0S + 4.22V + 0.69N + 0.9T + 1.29WS -2.87WV- 0.05WN +1.72WT - 0.13SV - 0.16SN + 3.7ST + 1.44VN+ 2.69VT - 0.85NT (5)

4. CHECKING THE ADEQUACY OF THE MODELS

The adequacy of the model was tested using Analysis of Variance (ANOVA) as explained byKumariet. al. [13] and Singla et al.[14].The scatter diagram for observed vs. estimated values of % dilution for different rows of the design matrix is given in figure 1.

TABLE 5: Analysis of variance (ANOVA)

Resp-onse	DOF		Var. response	Std. dev.	Var. adeq.	'F' model	'F' table	$F_m<F_t$
	S^2_Y	S^2_{ad}	S^2_Y	S_{bj}	S^2_{ad}	S^2_{ad}/S^2_Y	(10,16,0.05)	
%D	16	10	0.594	0.192	0.059	0.10	2.49	Yes

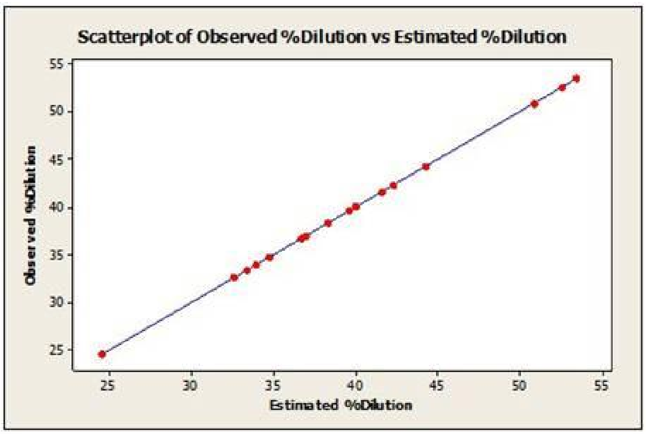

Fig. 1.Scatter plot for weld bead dilution model

The proposed model developed for %dilution after dropping insignificant coefficients is given in equation 6. Based on these models, graphs have been drawn for interpretation of the direct and interaction effects of the process parameters on %dilution.

%D= 39.72 -0.32W + 1.0 S + 4.22V -2.87 WV +1.72 WT - 0.13 SV + 2.69 VT (6)

5. OPTIMIZATION

Minimization of dilution was the main purpose of the present study while keeping in mind other important bead parameters with their constraints in the equation form. GA search ranges for delivering the optimal responses are given in Table 6. The experiments were carried out with the conditions as mentioned in Table 7.

Direct, indirect and response parameters for the selected set of problem are mentioned in Table 8.

TABLE 6: GA search ranges

Parameters	Units	Range
WireFeed Rate	m/min	7.62 - 9.04
Welding Speed	cm/min	27 - 36
Voltage	Volts	26 - 32
Nozzle to Plate Distance	mm	15 - 20
Torch Angle	Degree	80 - 100

TABLE 7.Experimental condition

Base Metal	IS 2062 steel of 10mm thickness
Deposited Alloy	TAFA 140MXC Nano-structured wire of 1.6 mm dia.
Welding conditions	Flat
Technique	Bead on plate
Process	Semiautomatic GMAW

TABLE 8. Direct, indirect and response parameters for the selected set of problem

Direct parameters	Indirect parameters		Response parameters
WireFeed Rate	Shielding gas	Argon	Penetration, p
Welding Speed	Power source	Constant potential	Width, w
Voltage	Welding current	D.C	Reinforcement height, h
Nozzle to Plate Distance	VI characteristic	Flat	%Dilution, D
Torch Angle	Electrode polarity	Positive	

GA optimization tool available in MATLAB R2009a, was employed for fulfilling the purpose of optimization. M-file was created which is shown below:

function [f,g]=fp(x)

```
f(1)= 39.72-0.3872*x(1)+1.0*x(2)+4.22*x(3)-2.87*x(1)*x(3)+1.72*x(1)*x(5)-0.13*x(2)*x(3)+2.69*x(3)*x(5);
g(1)= 8.51 + 0.62*x(1)-1.01*x(2)+1.54*x(3)+0.33*x(1)*x(2)+0.59*x(1)*x(5)-0.54*x(2)*x(3)+0.54*x(3)*x(5)-
0.24*x(4)*x(5);
g(2)= 5.5-8.51 + 0.62*x(1)-1.01*x(2)+1.54*x(3)+0.33*x(1)*x(2)+0.59*x(1)*x(5)-0.54*x(2)*x(3)+0.54*x(3)*x(5)-
0.24*x(4)*x(5);
g(3)= 4.01-0.32*x(2)-0.39*x(3);
g(4)= 3.0-4.01-0.32*x(2)-0.39*x(3);
g(5)= 3.91 + 0.18*x(1)-0.34*x(2)+0.19*x(3)-0.35*x(1)*x(3)+ 0.38*x(2)*x(5)+0.21*x(3)*x(4)+0.30*x(3)*x(5);
g(6)= 2.4-3.91 + 0.18*x(1)-0.34*x(2)+0.19*x(3)-0.35*x(1)*x(3)+ 0.38*x(2)*x(5)+0.21*x(3)*x(4)+0.30*x(3)*x(5);
g(7)= f-53.46;
g(8)= 24.5-f;
end
```

Parameters for GA computation and setting of GA graphical interface are given in table 9 and figure 2 respectively, Yoganandhet al.[15].

TABLE 9: Parameters for GA computation

Population type	Double vector	Crossover function	Intermediate
Population size	100	Migration	Forward
Number of generations	52	Lower boundary limits	-1, -1, -1, -1, -1.
Reproduction elite count	2	Upper boundary limits	1, 1, 1, 1, 1.

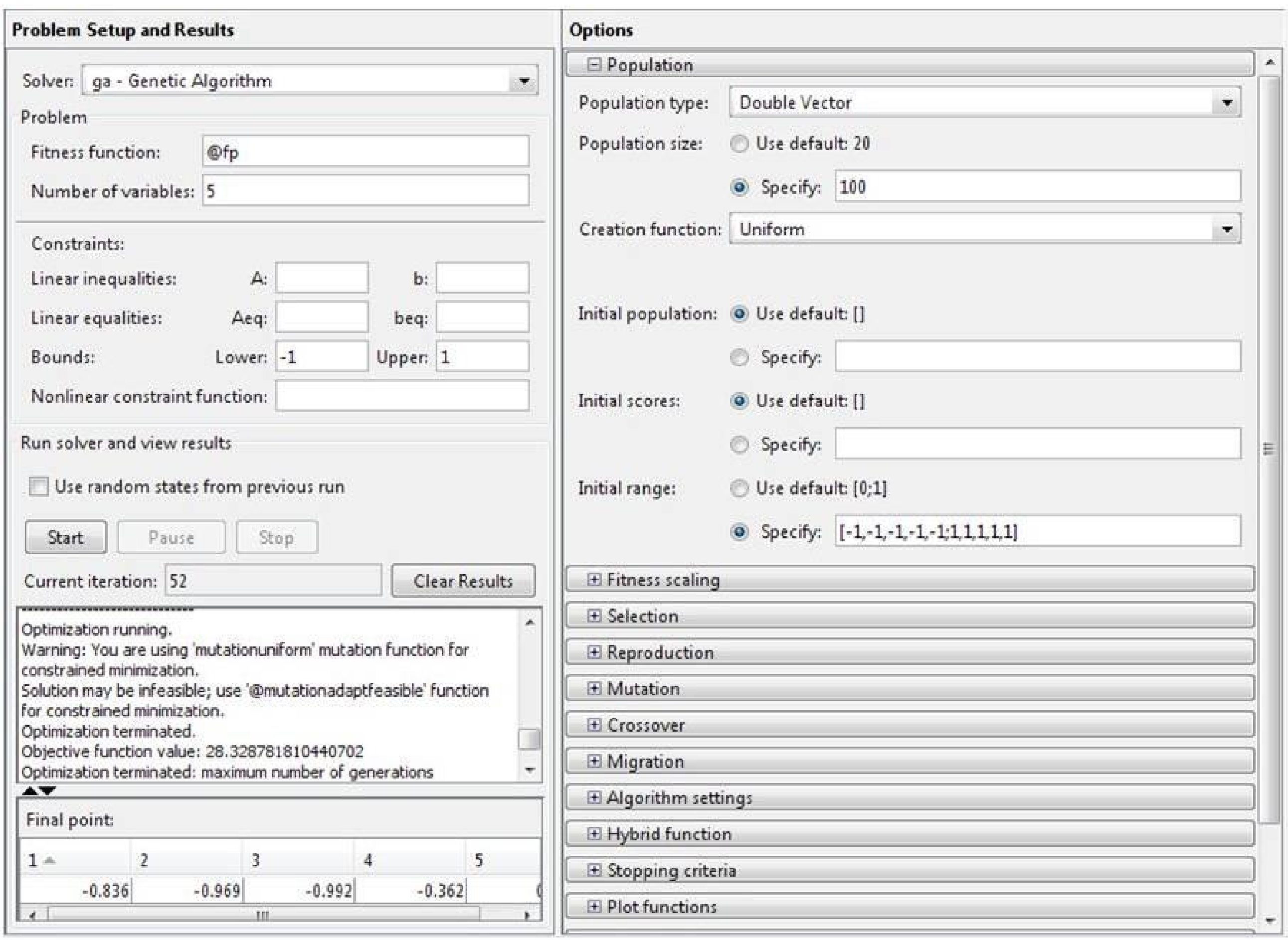

Fig. 2.GA algorithm tool

6. RESULT AND DISCUSSION

1. Increase in voltage, speed and torch angle increases the % dilution from 34.3 to 49.94,43.42 to 46.9and 32.8 to 50.44 respectively.
2. Increase in wire feed rate decreases the % dilution from 50.44 to 44.56.
3. % dilution remains constant at 46.03 with increase in nozzle to plate distance
4. Different coded values obtained after running the M-file are:

x(1) = Wire feed rate (W) = -0.836

x(2) = Welding speed (S) =-0.969

x(3) = Voltage(V) = -0.992

x(4) = Nozzle to plate distance (N) = -0.362

x(5) = Torch angle (T) = 0.866

Different plots for the developed code are shown in figure 3.The values of the direct parameter for the coded results and optimized response parameters of the hardfacedweldment are given in table 10.

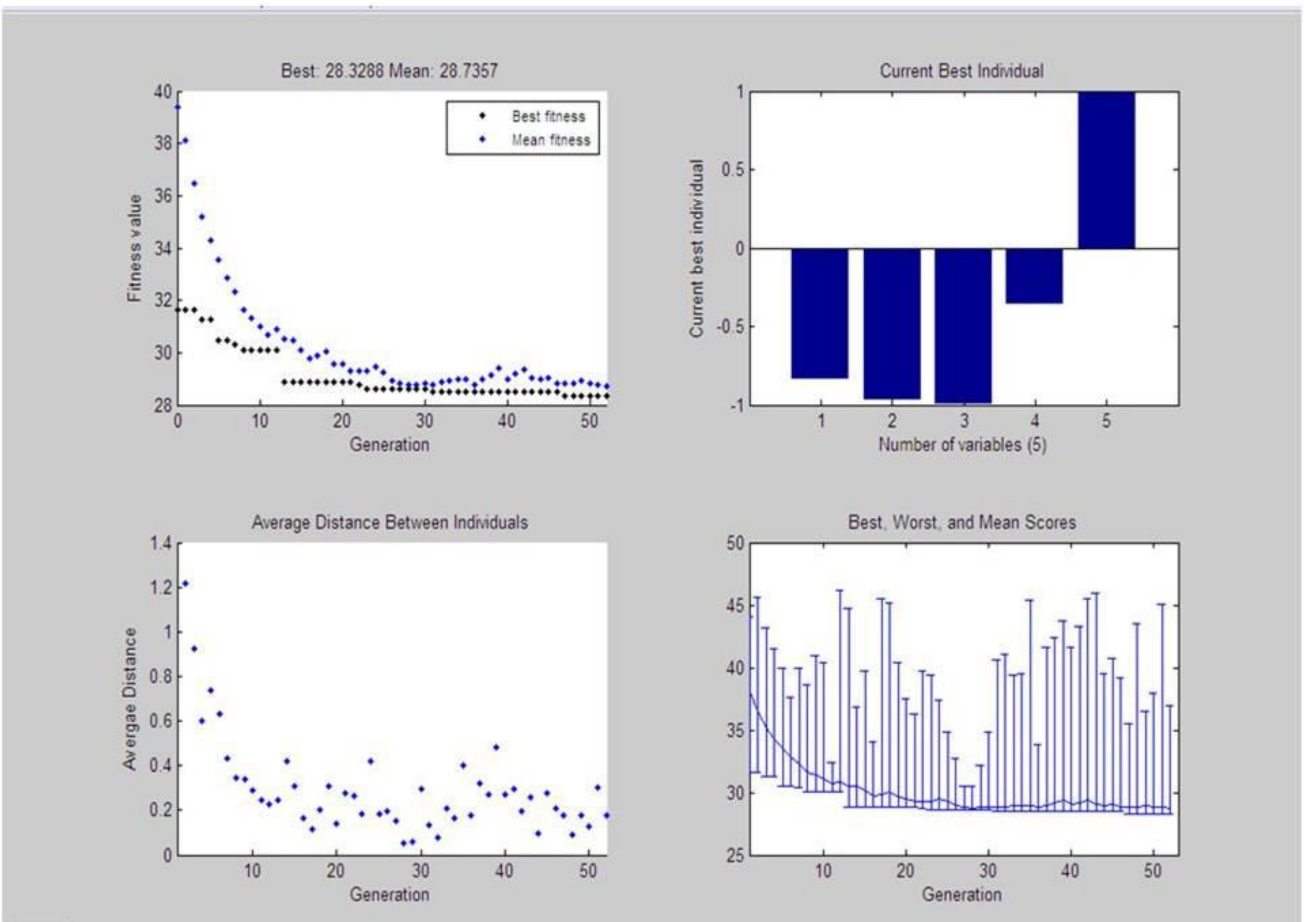

Fig. 3. GA output plots

TABLE 10. Values of optimized parameters

Direct parameter	Value	Response parameters	Value
WireFeed Rate	8.03322 m/min	%Dilution, D	28.3288
Welding Speed	29.31976 cm/min		
Voltage	27.512 V		
Nozzle to Plate Distance	17.0475 mm		
Torch Angle	94.33 ˚		

7. CONCLUSIONS

1. Response Surface Methodology (RSM) approach is an excellent and effective tool, for the development of mathematical model for the prediction of response.
2. Scatter diagram ensures the accuracy of the model.
3. Genetic Algorithm was found to be very effective and powerful technique for optimization of welding parameters.
4. Genetic Algorithm graphical user interface toolbox of MATLAB was used for minimization of dilution.
5. The optimum dilution obtained was 28.3288.
6. GMAW optimal process parameters were determined:

Wire Feed Rate = 8.03322 m/min; Welding Speed = 29.31976 cm/min; Voltage = 27.512V; Nozzle to Plate Distance = 17.0475 mm; Torch Angle = 94.33˚.

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Study of Combustion and Emission Characteristics of Diesel Engine at Variable Compression Ratio using Low Percentage Waste Cooking Oil Methyl Ester

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***Abstract*—The global energy requirement is constantly increasing due to increased mobility, industrialization and improved living standards and most of this energy is produced from use of fossil fuels. Hence, it is fairly necessary to search some alternative fuels which may be produced from available resources such as ethanol, alcohol, biodiesel, vegetable oils etc. Therefore biodiesel is a biofuel that seems a viable solution as an alternative fuel to meet the energy demands. This paper evaluates the combustion characteristics and emission studies of a unmodified four stroke single cylinder variable compression ratio diesel engine utilizing blends of waste cooking oil methyl ester (WCME) with standard neat diesel fuel. Fuel sample were prepared from blends of 15% by volume WCME15, 20% by volume WCME20 and 25% by volume WCME25 with standard diesel fuel. Experimental tests were performed to study the combustion characteristics viz. Peak cylinder pressure, heat release rate and emissions of CO, CO_2, HC and NO_x at variable compression ratios of 16, 17,18 and at different engine loads. It has been observed that the peak cylinder gas pressure for WCME20 and WCME25 was measured higher than standard diesel fuel at compression ratio 18 whereas WCME15 showed lower value than WCME20 and WCME25. Results showed the highest peak heat release for WCME25 than all other fuel samples and standard diesel fuel at compression ratio 18 though it was obtained highest for WCME20 at compression ratio 17. It was observed that HC, CO and CO_2 emissions decreased significantly for all biodiesel samples at all compression ratios than that of standard diesel. WCME20 showed the lowest CO and CO_2 emissions and slightly higher CO and CO_2 emission were reported for WCME15 at compression ratio 18. While at compression ratio 17 WCME25 exhibited the minimum CO and CO2emissions. However increase in NO_x emission was reported maximum for WCME25 in comparison with all other fuels.**

I. Introduction

Energy plays a significant role in economic growth, social development and human welfare. However, with increasing industrialization, the world energy demand is also growing by leaps and bounds. Since their exploration, the petroleum fuels have continued as major conventional energy source, however, these fuels are not only limited but also release hazardous emission to the environment. Recent upsurge in petroleum prices and environmental degradation caused by petroleum derived fuels have mandated the need to explore alternatives to conventional petroleum fuels.[1,2]. The International Energy Agency (IEA) forecasts that world primary energy demand between now and 2030 will increase by 1.5% per year Oil and other petroleum products are also expected to continue to account for the largest share of world energy consumption, but their share is likely to fall over the next couple of years mainly due to increasing world oil prices. Petroleum and other liquid fuels will remain the most important fuels for transportation in the coming years as there are few alternatives that can be expected to compete widely with petroleum-based liquids. The share of biofuels is also expected to increase in the coming years. However there is a significant resource issue that will need to be addressed.[3,4]

Utilization of Biofuels has been expected to increase three fold, (from 1.3 million barrels of oil equivalent per day (mboe/d) in 2010 to 4.5 mboe/d as per the new policies, in 2035), driven primarily by blending mandates. Ethanol remains the dominant biofuel, with supply rising from 1 mboe/d in 2010 to 3.4 mboe/d in 2035. Biofuels meet 37% of road transport demand in 2035 in Brazil, 19% in the United States and 16% in the European Union [5]. India is highly dependent on import of crude oil. Net imports of crude oil have increased from 99.41MTs during 2005-06 to 184.80 MTs during 2012-13. Whereas Consumption of Crude Oil have increased from 130.11MMT to 219.21MMT [6]. The serious problem associated with the use of conventional petroleum fuel is the increase in pollutants emissions like CO_2, HC, NO_x, SO_x and many other nasty gasses. These gases are detrimental to the biodiversity along with adverse effect on human health [7]. In recent years, due to increased environmental concerns, depletion of petroleum resources, and several other socioeconomic aspects have driven research to develop alternative fuels from renewable resources that are cheaper and environmentally acceptable [8]. Biodiesel can be one of the best alternatives. The use of vegetable oils as alternative renewable fuel competing with petroleum was proposed in the beginning of 1980s. It is made from the oils of various types of oilseed crops like sunflower, palm, cottonseed, rapeseed, soybean, linseed etc. The biodiesel fuel (vegetable oils processed with methanol or ethanol) is a renewable fuel, so it is non-toxic and does not increase the level of CO_2 at all in the atmosphere at global level. The exhaust emission of the fuel absolutely does not have SO_x, and considerably less amount of NO_x are produced.[9,10]

Vegetable oils could be used as alternative fuels in compression ignition engine vehicles under normal operating conditions and Vegetable oils are available everywhere in the world, they are renewable as the vegetables which produce oil seeds can be planted year after year. Several countries including India have already begun substituting the conventional diesel by a certain amount of biodiesel. [11-13]

Several researchers conducted a number of investigations using several vegetables oils such as coconut oil sunflower, palm, cottonseed, rapeseed, soybean etc. as an alternative fuel, and the test results indicated that using biodiesel in diesel engines significantly reduce exhaust emissions viz. PM, HC, CO emissions, due to higher cetane number,higher oxygen contents compared with diesel fuel. It is biodegradable, renewable, carbon neutral, and does not produce hazardous toxic It has been proved that vegetable oils are feasible substitutes for diesel fuel.[14-23]. However, due to lack of vast study of performance, combustion and emission characteristics using waste cooking oil, it is gaining recently attraction of researchers for investigations. Also results at different compression ratio is also point of attraction [24-27] Therefore present work has been investigated using waste vegetable oil.

II. EXPERIMENTAL SETUP

In the present work waste cooking oil was made available from a restaurant and to reduce free fatty acids found in waste cooking oil, a transesterification process was performed. Unrefined waste cooking oil, methanol, sulfuric acid and a catalyst KOH were used for esterification to reduce the free fatty acid content to the required level (<0.5 wt.%). the refined waste cooking oil was separated from the resulting glycerol solution and was treated further to obtain methyl ester of waste cooking oil(WCME).methanol. The fuel samples were prepared (%by volume) by addition of WCME in standard diesel fuel. Three blends were prepared from 15% by volume waste cooking oil methyl ester and 85% standard diesel fuel (WCME15), 20% by volume waste cooking oil methyl ester and 80% standard diesel fuel (WCME20), 25% by volume waste cooking oil methyl ester and 75% standard diesel fuel (WCME15).To inspect homogeneity and stability all blends were kept undisturbed for a month and were found homogenous and stable after centrifuge test.

The major fuel properties of various blends and standard diesel fuel are shown in Table 3. Experiment on all fuel samples were conducted on a single cylinder 4 stroke diesel engine. All the tests were performed at no load to full load condition. The engine set up used in the tests is shown in Fig, 1. The different combustion parameters were measured from engine set up. AVL DI Gas analyzer was used to measure the HC, CO, NOX and CO2 emissions. The specification of the diesel engine is shown in Table 1. Whereas the specifications of AVL DI Gas analyzer and AVL Smoke meter is shown in Table 2.

TABLE 1: ENGINE SPECIFICATION

Make	Kirloskar, India
Product	VCR Engine Setup
Rated Brake Power (kw)	3.50
Rated Speed(rpm)	1500
Number of Cylinder	One
Bore (mm)	87.5
Stroke (mm)	110.0
Connecting Rod length (mm)	234.0
Swept volume (cc)	661.45
Compression Ratio(variable)	12-18
Cooling System	Water Cooled
Lubrication System	Forced Feed
Piezo sensor	Range 5000 PSI, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse

TABLE 2: SPECIFICATIONS OF AVL DI GAS ANALYZER

Emission	Range	Resolution
HC	0-20 ppm vol.	1 ppm
CO	0-10% vol.	0.01% vol
CO_2	0-20% vol	0.1% vol
NO_X	0-5 ppm vol	1 ppm

TABLE 3:THE FUEL PROPERTIES

Fuel Properties	WCME 15	WCME 20	WCME 25	WCME 100	Diesel Fuel
Density (kg/m3)	841.7	844.5	846.3	874.8	832.6
Viscosity (mm2/s)	3.118	3.198	3.476	4.256	2.946
Calorific value (MJ/kg)	44.543	45.371	45.834	41.671	47.231

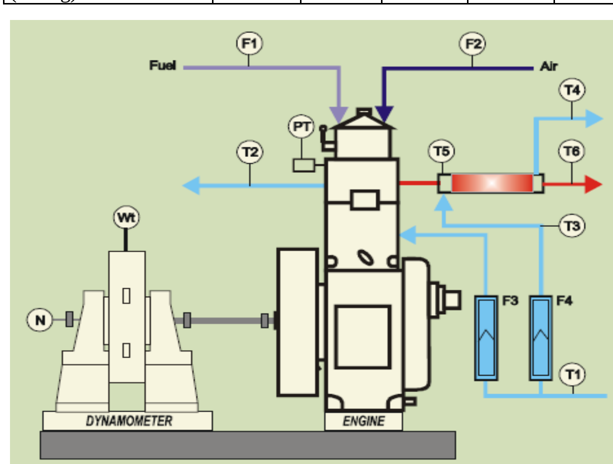

Fig. 1: Engine Set Up

III. Results and Discussion

A. Combustion Characteristics

1) Cylinder gas pressure

The variations in the cylinder pressure with crank angle for diesel and WCME for three compression ratio 16, 17 and 18 are shown in Fig. (2–4). It has been observed that at compression ratio 18, the peak cylinder gas pressure for WCME20 and WCME25 were obtained higher than standard diesel fuel. Whereas WCME15 showed lower value than WCME20 and WCME25. The similar results were seen for compression ratio 17 and 16 Fig. It may be due to the higher rate of heat release during premixed combustion phase. Results are confirmed by earlier investigations. [28-30].

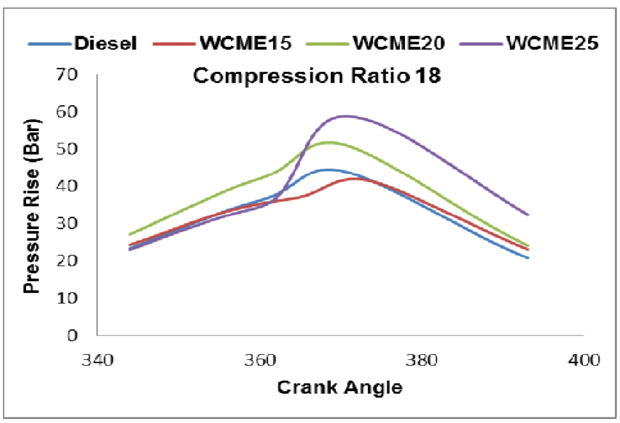

Fig. 2: Cylinder Pressure Variation

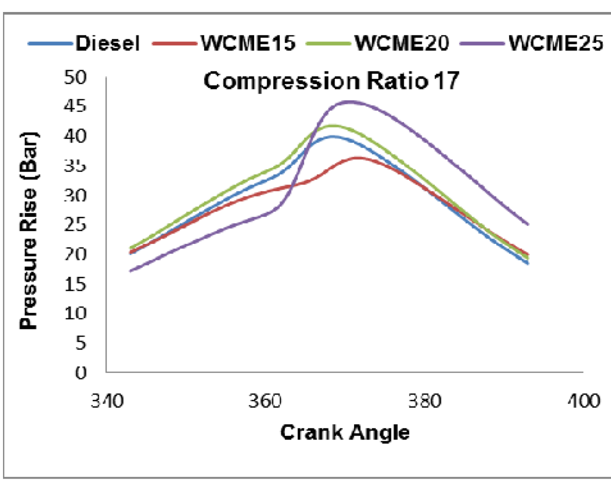

Fig. 3: Cylinder Pressure Variation

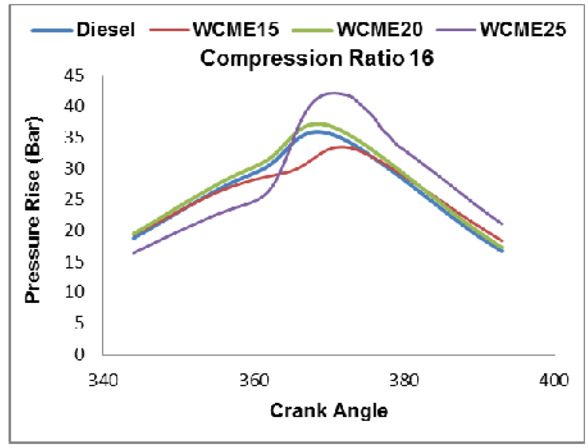

Fig. 4: Cylinder Pressure Variation

2) Net heat release rate

Figures(5-7) show the heat release rate for compression ratio 16,17 and 18. Results indicate that for compression ratio 18 the highest peak heat release for WCME25 than all other fuel samples and standard diesel fuel though because at higher compression ratio and due to presence of enriched oxygen in the biofuel combustion will be proper and hence the net heat release rate will be high for 25 % blend condition. As far as CR 17 is concern WCME20 has highest peak this is due to the fact that at lower compression ratio upto 20 % blending condition better combustion is obtained. Also the low viscosity of the blended fuel and the presence of oxygen in the fuel help in proper burning of fuel. Beyond 20 % blend it has been seen that the peak of heat release is low because of increase in viscosity, Whereas at compression ratio 16 diesel fuel exhibited highest heat release among all fuels. The most widely used approach to measure the heat release analysis (Qn) was developed by Krieger and Borman [31] which is given in Eq. (1). Where, λ is the ratio of specific heats which was taken as 1.35, θ is crank angle, P is cylinder gas pressure, and V is cylinder volume

$$Qn = \frac{\lambda}{\lambda-1} P \frac{dV}{d\theta} + \frac{1}{\lambda-1} V \frac{dP}{d\theta} \qquad (1)$$

Because of the evaporation of the fuel accumulated during ignition delay period, at the beginning a negative heat release rate is observed After the ignition delay, premixed fuel–air mixture burns rapidly, follow by diffusion combustion, where the burn rate is controlled by fuel–air mixing velocity. The consistency in results may be agreed by earlier research results. [32,33]

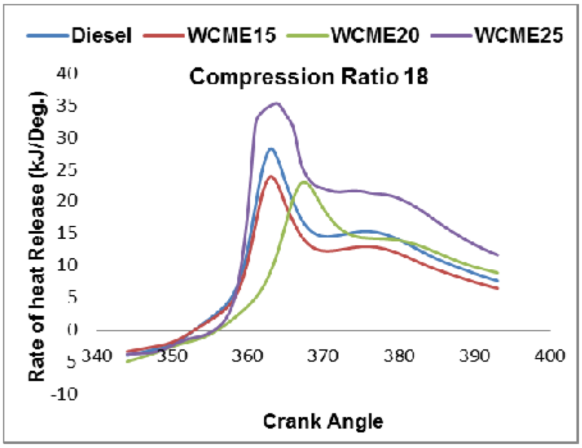

Fig. 5: Variation of Heat Release

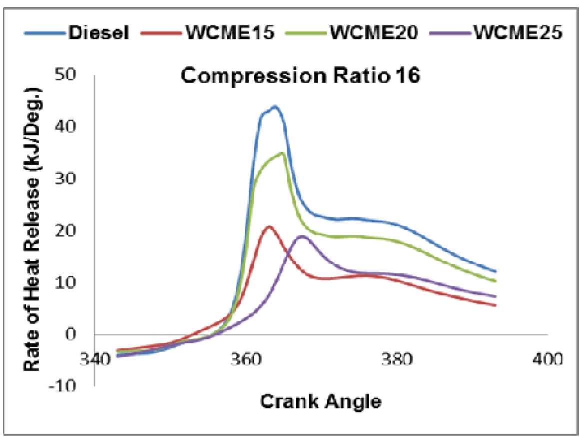

Fig. 6: Variation of Heat Release

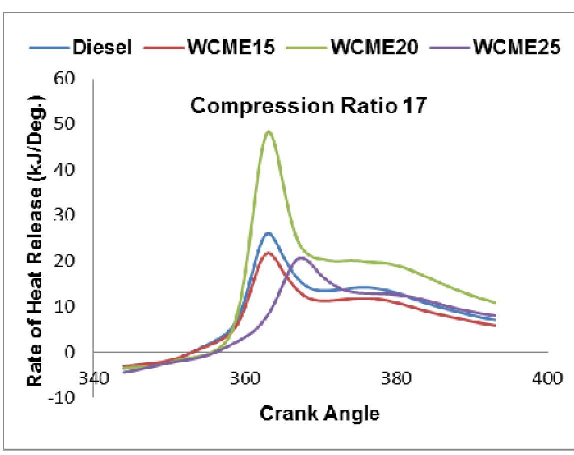

Fig. 7: Variation of Heat Release

B. *Emission Characteristics*

Exhaust emission viz. HC, CO, CO_2 and NO_x were measured byAVL DI Gas analyzer. Characteristics of emissions are explained below:

1) *HC emission*

From above Figures (8–10) it was observed that HC, emissions decreased significantly for all biodiesel samples WCME15, WCME20 and WCME25 at all compression ratios than that of standard diesel. As reported by other authors, the oxygenated compounds of the biodiesel and higher cetane number of biodiesel improve the fuel oxidation reducing HC emissions [1,34]

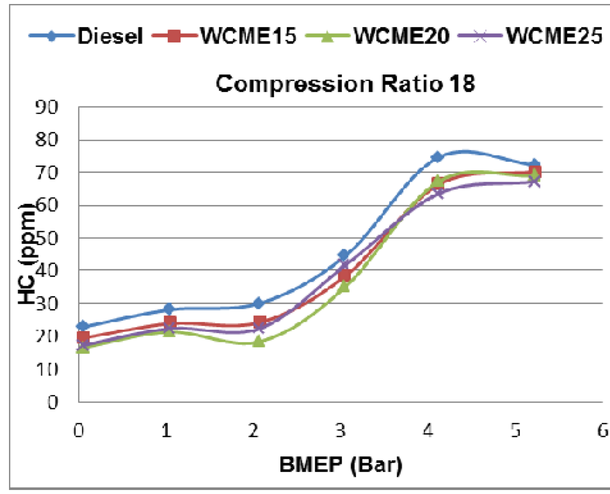

Fig. 8

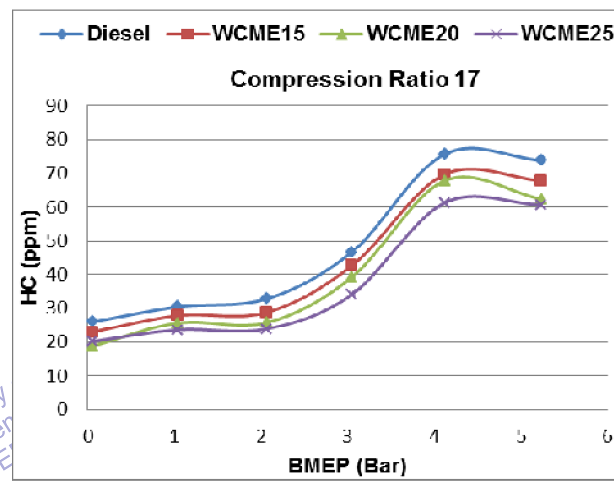

Fig. 9

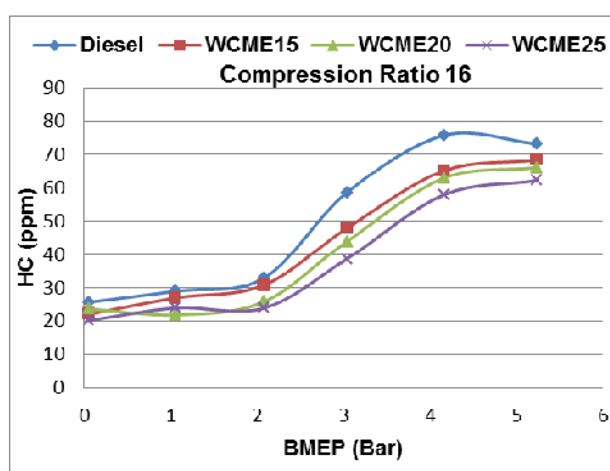

Fig. 10

2) *CO and CO_2 emission*

Emissions of CO and CO_2 are explained in Fig. (11-16). It was reported that significant reduction of CO and CO_2 emissions for all biodiesel samples at all compression ratios than that of standard diesel. WCME20 showed the lowest CO and CO_2 emissions and slightly higher CO and CO_2 emission were reported for WCME15 at compression ratio 18. While at compression ratio 17 WCME25 exhibited the minimum CO and CO_2emissions. CO emissions appear due to a non-complete combustion in which some hydrocarbons are not oxidized to CO_2 and CO emissions are strongly coupled with HC emissions [35]

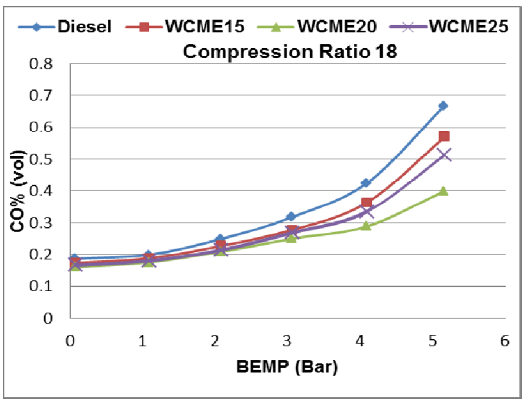

Fig. 11

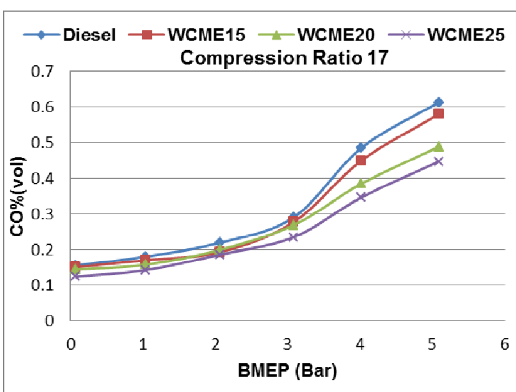

Fig. 12

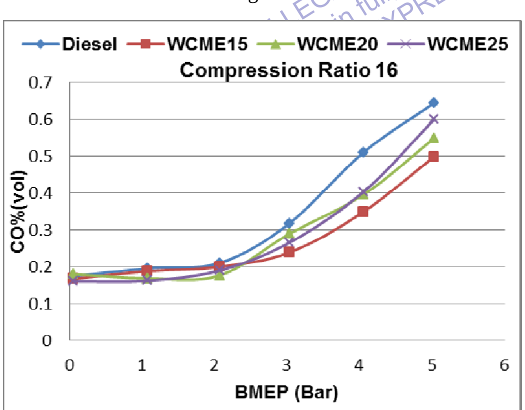

Fig. 13

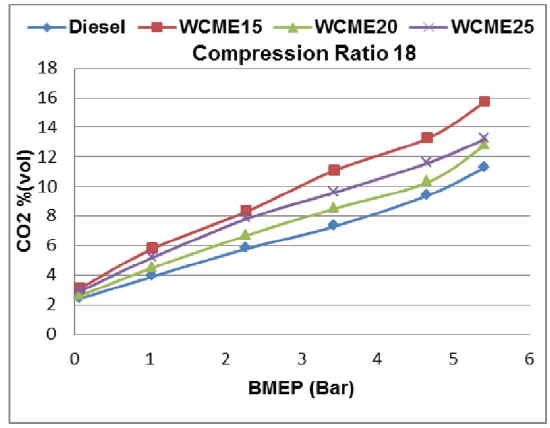

Fig. 14

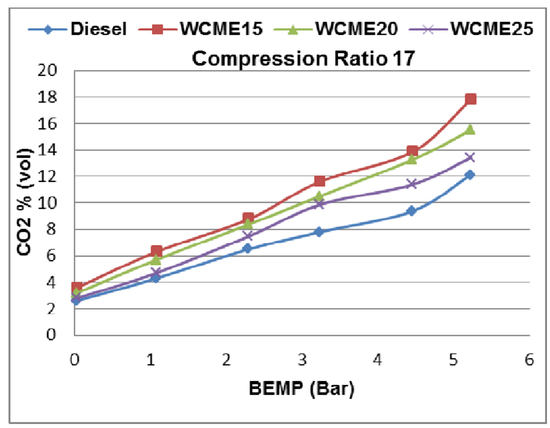

Fig. 15

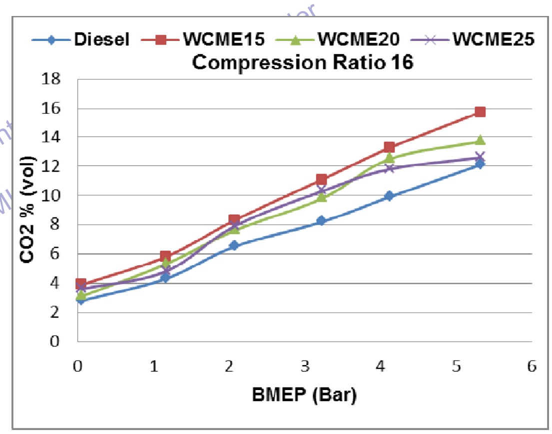

Fig. 16

3) *NO_x emission*

Figures (17-19) show the variation of NO_x for all fuel samples and standard diesel fuel However increase in NO_x emission were reported maximum for WCME25 in comparison with all other fuels. It was explained that the higher cetane number of the biodiesel reduces the ignition delay. Reducing ignition delay increases NOx emissions since the residence time of the burning mixture in the cylinder increases [36].

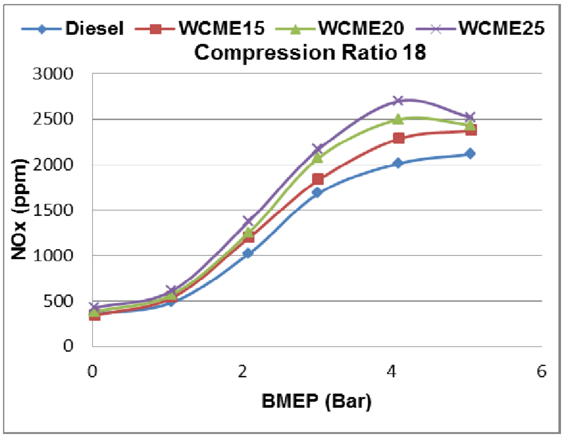

Fig. 17

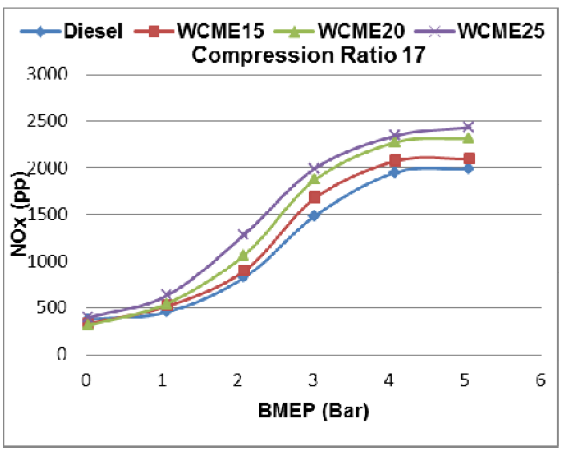

Fig. 18

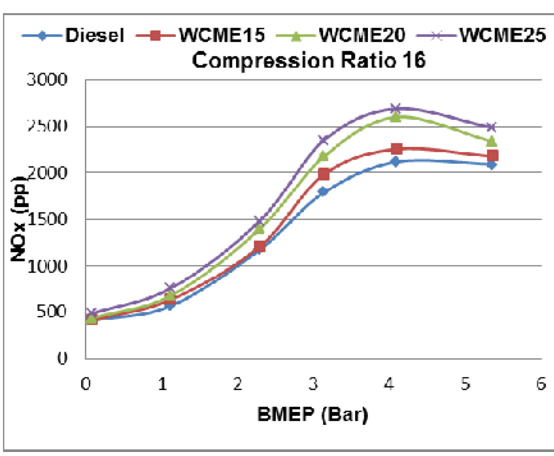

Fig. 19

IV. CONCLUSION

Waste cooking oil methyl ester has shown very favorable characteristics as an alternative fuel in comparison with standard diesel fuel. The following conclusions are drawn from the experiments conducted for evaluation of combustion and exhaust emission behavior of waste cooking oil methyl ester relative to standard diesel biodiesel in a direct injection diesel engine.

1. Fuel samples WCME25 and WCME20 showed 16% and 31% increase in, the peak cylinder gas pressure at compression ratio 18 than standard diesel fuel. It may be due to the higher rate of heat release during premixed combustion phase.
2. At compression ratio 18 the highest peak heat release for WCME25 than all other fuel samples and standard diesel fuel though it was obtained highest for WCME20 at compression ratio 17. Whereas at compression ratio 16 diesel fuel exhibited highest heat release among all fuels
3. Because of the evaporation of the fuel accumulated during ignition delay period, at the beginning a negative heat release rate is observed After the ignition delay, premixed fuel–air mixture burns rapidly, follow by diffusion combustion.
4. At compression ratio 18, HC emissions for fuel samples WCME15, WCME20 and WCME25 were found to be decreased by 6.5%, 9.6% and 15% respectively than that of standard diesel. Which is due to the oxygenated compounds of the biodiesel and higher cetane number of biodiesel improve the fuel oxidation reducing HC emissions.
5. Emissions of CO and CO2 are reduction of CO and CO2 emissions for all biodiesel samples at all compression ratios CO emissions appear due to a non-complete combustion in which some hydrocarbons are not oxidized to CO2 and CO emissions are strongly coupled with HC emissions
6. Emissions of NOx increased for all fuel samples and it was reported maximum for WCME25 in comparison with all other fuels. The higher cetane number of the biodiesel reduces the ignition delay. Reducing ignition delay increases NOx emissions.

Consequently it can be concluded that on the basis of combustion performance and exhaust emission results, biodiesel Waste cooking oil methyl ester and its blends with diesel fuel can be utilized in the engine at compression ratio 17 and 18 effectively without any modification.

Abbreviations

% - Percentage.

BMEP - Brake Mean Effective Pressure.

CO - Carbon Monoxide

CO_2 - Carbon Dioxide.

cst- Centi Stroke

HC - Hydrocarbon

KJ - kilo joule

WCME- Waste cooking oil methyl ester

WCME 100 - Neat Waste cooking oil methyl ester

WCME 15 - 15% WCME and 95% Neat Diesel

WCME20- 20% MOME and 80% Neat Diesel

WCME25- 25% MOME and 75% Neat Diesel

MT - Million Tonne.

MBOE - Million Barrels of Oil Equivalent

NOx- Nitrogen Oxides.

ppm- Parts Per Million.

PM - Particulate matter

THC - Total Hydrocarbon

SO_X- Sulphur oxide

KOH- Potassium Hydroxide

Wt.-Weight

TDC-Top dead centre

T1 – supply water temperature (^oC)

T2 – temperature of water inside jacket (^oC)

T3 – supply water temperature for calorimeter (^oC)

T4 – temperature of water leaving the calorimeter (^oC)

T5 – exhaust gas temperature (^oC)

T6 –temperature of exhaust leaving the calorimeter (^oC)

F1 – fuel flow rate (cc/min)

F2 – air flow rate (cc/min)

F3 – water flow rate for engine cooling (cc/min)

F4 – water flow rate for calorimeter (cc/min)

N – Crank angle sensor

Wt– Loading from dynamometer

PT – sensor

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Comparative Analysis of Performance and Exhaust Emission of Variable Compression Ratio Engine Utilizing Blends of Waste Cooking Oil and Linseed Oil as an Alternative Fuel

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Abstract: *Biodiesel is an alternative fuel for petroleum-derived diesel and a high potential renewable energy source which can be used in existing diesel engine without modification. Numerous researchers are still examining the suitability of utilization of edible and non-edible oils in compression ignition engines. In the present work an experimental analysis was performed to compare the performance and exhaust emission effects of variable compression ratio engine utilizing waste cooking oil methyl ester (wcme) and linseed oil methyl ester (lme) blends. In the experiment content of waste cooking oil methyl ester (wcme) biodiesel was varied as 15% (wcme15), 20%(wcme20) and 25%(wcmedld25) with neat standard diesel whereas the second fuel, linseed methyl ester (lme) was also prepared with similar proportions as lme15, lme20 and lme25. All experiment tests were performed with engine speed 1500 rpm and variable compression ratio 17 and 18 at different load conditions. The effect of blends and compression ratio on different performance parameters viz. Brake thermal efficiency (bte), brake specific fuel consumption (bsfc), and exhaust gas temperature along with emissions co, co2, hc and* no_x*, was investigated and thus compared with different blends of both fuels. Results showed that lme exhibited the prominent engine performance and exhaust emissions compared to wcme.*

Keywords: *Linseed Methyl Ester, Waste Cooking Oil Methyl Ester, Variable Compression Ratio*

1. INTRODUCTION

The inadequate resources of fossil fuels, rise in crude petroleum prices, and serious ecological concerns have directed to the search of alternative fuels, [1,2] the international energy agency (iea) forecasts that world primary energy demand between now and 2030 will increase by 1.5% per year oil and other petroleum products are also expected to continue to account for the largest share of world energy consumption. It is predictable that the share of biofuels will increase in the coming years.[3,4]. India is highly dependent on import of crude oil. Net imports of crude oil have increased from 99.41mts during 2005-06 to 184.80 mts during last year. Whereas consumption of crude oil have increased from 130.11mmt to 219.21mmt[5]. The serious problem associated with the use of conventional petroleum fuel is the increase in pollutants emissions like co_2, hc, no_x, so_x and many other hazardous gasses. These gases are detrimental to the biodiversity along with adverse effect on human health [6]. Therefore in recent years, several other socioeconomic aspects have driven research to develop alternative fuels from renewable resources that are cheaper and environmentally acceptable [7] biodiesel can be one of the best alternatives. The use of vegetable oils as alternative renewable fuel competing with petroleum was proposed in the beginning of 1980s. It is made from the oils of various types of oilseed crops like sunflower, palm, cottonseed, rapeseed, soybean, linseed etc. The biodiesel fuel (vegetable oils processed with methanol or ethanol) is a renewable fuel, so it is non-toxic and does not increase the level of co_2 at all in the atmosphere at global level. The exhaust emission of the fuel absolutely does not have so_x, and considerably less amount of no_x are produced.[8-12]however, due to lack of vast study of performance, combustion and emission characteristics using waste cooking oil, it is gaining recently attraction of researchers for investigations [13,14]. Therefore present work has been investigated using waste vegetable oil and linseed oil methyl esters.

A number of studies of performance combustion and emission utlising a variety of biodiesel have been carried out and for a comprehensive review, some of the research findings are summarized below

Silvio et. Al. [2002] investigated engine performance and emissions using pure palm oil as an alternative fuel. Engine performance and emissions were influenced by basic differences between diesel fuel and palm oils such as mass based heating values, viscosity, density and molecular oxygen content. They also concluded that the specific fuel consumption of palm oil was found almost 10% higher than diesel at low loads [15].

Agarwal et. Al.(2006) studied the combined effect of biodiesel and exhaust gas recirculation (egr) in ci engines which resulted in reduction of nox, hc and co and smoke. However egr increases the hc and co emissions without compromising engine performance and emissions.[16].

Banapurmath et. Al. [2008] compared performance of di engine fuelled with neat diesel, methyl esters of honge oil, jatropha and sesame oils. Resultsshowed a slightly reduced thermal efficiency and poor performance with all the esters[17].

Prem anand et. Al.(2010) performed experiment to evaluate the exhaust emission characteristics using turpentine oil fuel (tpof) blended with conventional diesel fuel (df) fueled in a diesel engine. Observation results explain the reduction of hc, co emissions is mainly due to the effect of complete combustion for increasing tpof in blends. It is also observed that due to low temperature combustion of tpof blend, maximum reduction of nox emission is obtained[18].

Violeta et. Al. [2014] utilized microalgae oil methyl esterstoanalyze performance characteristics of diesel fuel. Result showed that ateach engine load, the brake-specific fuel consumption was approximately 3–3.5% higher with rapeseed oil methyl esters (b30rme) and algae oil methyl esters (b30ame) than mineral diesel fuel, while running on (b30ame), the engine's thermal efficiency was 2.5–3% higher compared to mineral diesel fuel[19].

2. EXPERIMENTAL SETUP

In the present study waste cooking oil methyl ester was made accessible from a restaurant whereas linseed oil methyl ester was prepared from raw linseed oil. The transesterification process was performed by converting the triglycerides of vegetable oils to their monoester by reacting them with alcohols in the presence of a catalyst to reduce viscosity and improve cetane number of fuels. The fuel samples were prepared (%by volume) by addition of wcme and lme in standard diesel fuel. Proportions of three blends of wcme and lme were varied as 15% (wcme15, lme15), 20%(wcme20, lme20) and 25%(wcme25, lme25) by volume with neat standard diesel. Homogeneity and stability of all blends were inspected thoroughly.

The main fuel properties of various blending stocks and standard diesel fuel are shown in table 1. Cetane number for different blend was estimated as follows:

$$Cn_h = \sigma_i \, cn_i * x_i$$

Where cn_h is the equivalent cetane number of the blended fuel, while cn_i is the cetane number of each constituent. [20, 21]

The engine used in experiment was a single cylinder, naturally aspirated, four stroke, and direct injection diesel engine. Experiment tests were performed with engine speed 1500 rpm and variable compression ratio 17 and 18 at different load conditions. The engine set up used in the tests is shown in fig.1. There are different methods to achieve different compression ratio, one of them is tilting cylinder block arrangement which was given in setup to vary the combustion space volume for change in compression ratio. This is achieved without stopping the engine and altering the combustion chamber geometry. The arrangement consists of a tilting block with six allen bolts, a compression ratio adjuster with lock nut, and compression ratio indicator. For a chosen compression ratio within the range given, the allen bolts provided for clamping the tilting block are loosened slightly. The lock nut is loosened on the adjuster and the adjuster is rotating to set the compression ratio on the compression ratio indicator marking. Thus locking the adjuster by the lock nut and all the allen bolts are to be tightened gently. The different performance parameters were measured from engine set up. AVL di gas analyzer was used to measure the HC, CO, NO_x and CO_2 emissions. The specification of the diesel engine is shown in table 2. Whereas the specifications of avl di gas analyzer and avl smoke meter is shown in table 3.

TABLE 1: The Fuel Properties

FUEL PROPERTIES	WCME15	WCME20	WCME25	WCME100	LME15	LME20	LME25	LME100	DIESEL
DENSITY (KG/M3)	841.7	845	846.3	874.8	832.8	833.1	833.7	835.8	832.6
VISCOSITY (MM2/S)	3.118	3.2	3.476	4.256	3.156	3.214	3.271	4.256	2.946
CALORIFIC VALUE (MJ/KG)	44.54	45.4	45.834	41.67	45.781	45.521	44.981	38.17	47.231
CETANE NUMBER	47	47	47	46	48	48	48	47	48

TABLE 2: Engine Specification

MAKE	KIRLOSKAR, INDIA
PRODUCT	VCR ENGINE SETUP
RATED BRAKE POWER (KW)	3.50
RATED SPEED(RPM)	1500
NUMBER OF CYLINDER	ONE
BORE (MM)	87.5
STROKE (MM)	110.0
CONNECTING ROD LENGTH (MM)	234.0
SWEPT VOLUME (CC)	661.45
COMPRESSION RATIO(VARIABLE)	12-18
FUEL INJECTION STARTS BEFORE TDC	23^0
COOLING SYSTEM	WATER COOLED
LUBRICATION SYSTEM	FORCED FEED
PIEZO SENSOR	RANGE 5000 PSI, WITH LOW NOISE CABLE
CRANK ANGLE SENSOR	RESOLUTION 1 DEG, SPEED 5500 RPM WITH TDC PULSE

TABLE 3: Specifications Of Avl Di Gas Analyzer

EMISSION	RANGE	RESOLUTION
HC	0-20 PPM VOL.	1 PPM
CO	0-10% VOL.	0.01% VOL
CO_2	0-20% VOL	0.1% VOL
NO_X	0-5 PPM VOL	1 PPM

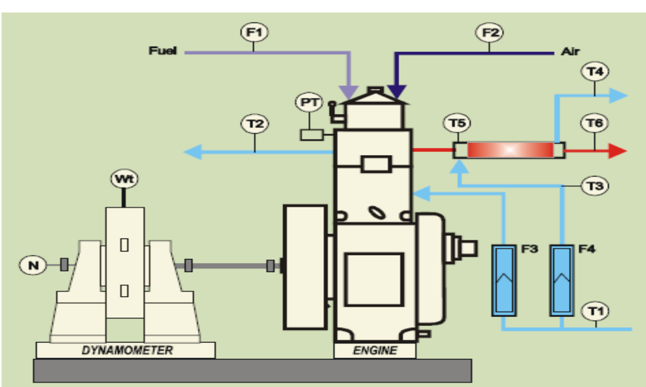

Fig. 1. Engine Set Up

3. RESULTS AND DISCUSSION

3.1 PERFORMANCE CHARACTERISTICS

The variation of brake thermal efficiency (bte) and brake specific fuel consumption (bsfc) and exhaust gas temperature(egt) with brake mean effective pressure (bmep) for the fuel samples wcme15, wcme20, wcme25 and lme15, lme20, lme25 with standard diesel at compression ratio 18 and 17 is shown in figures (2-10).

3.1.1 BRAKE THERMAL EFFICIENCY

It was observed that increase in brake power; caused increase in thermal efficiencies of all the fuels at part load condition figures(2,3) but on further increment, bte of all fuels at compression ratio (cr) 18 and cr17 were reported a lower than diesel fuel.

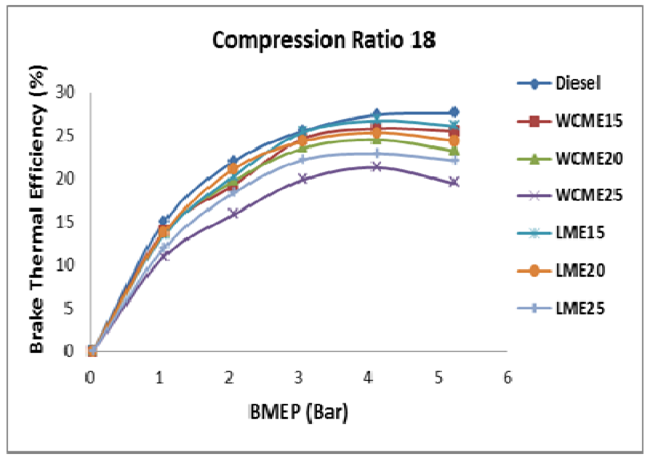

Fig. 2. Variation of brake thermal efficiency with brake mean effective pressure at cr 18

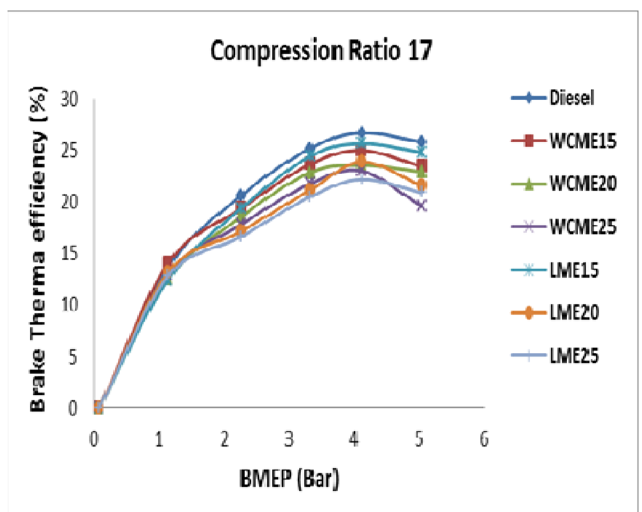

Fig. 3. Variation of brake thermal efficiency with brake mean effective pressure at cr 17

Further at cr 18 and cr 17 lme15 showed bte very close to diesel fuel. Though at cr 18 and cr 17, wcme25 showed minimum efficiency. This is due to the fact that biodiesel have higher viscosity and lower heating value than diesel fuels. Reduction in lower calorific value and high viscosity cause improper atomization of the blends as compared to diesel fuel. It was reported that the bte increases with increase in load due to the fluctuations in engine speed and power output. These results are correlated with the result obtained by nadir yilmaz. Et. Al.[22].

3.1.2 BRAKE SPECIFIC FUEL CONSUMPTION (BSFC)

It can be seen from figures (4,5) that at cr 18 and cr17, bsfc for all fuel samples is found to be higher than that of diesel fuel. While at cr 18 and cr17, bsfc for lme25 is close to diesel fuel. Wcme15 exhibited highest bsfc at cr 18 and cr 17.

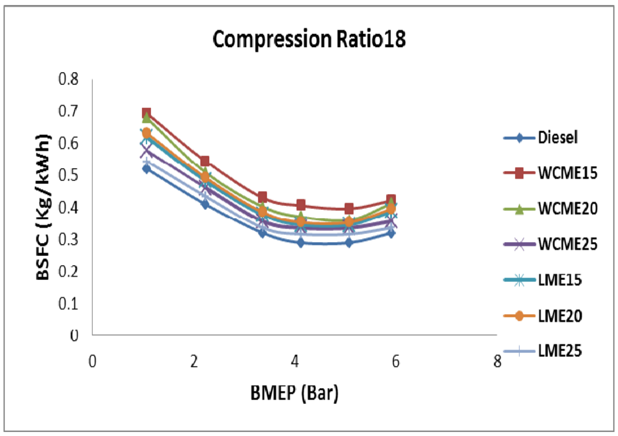

Fig. 4. Variation of bsfc with brake mean effective pressure at cr 18

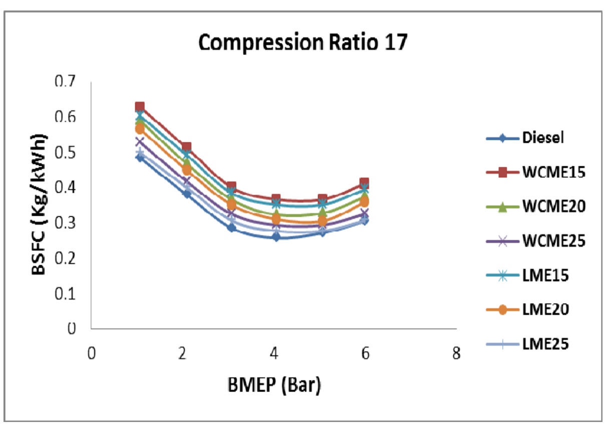

Fig. 5. Variation of BSFC with brake mean effective pressure at cr 17

The higher amounts of oxygen present in the considered blends may lead to lower bsfc . It was observed that at higher temperature viscosity decreases which leads to better atomization and combustion and results in lower brake specific fuel consumption. Results obtained are similar to those obtained by bhupendra et. Al.[23].

3.1.3 EXHAUST GAS TEMPERATURE(EGT)

Experiment results showed figures (6,7) that the increase in brake power causes increase in exhaust gas temperature for all fuels. At cr18, lme15 showed the highest value of exhaust gas temperature of 406^{0}c but slightly lower than that of diesel with temperature of 425^{0}c. Though lowest temperature of 352^{0}c was obtained for lme 25.

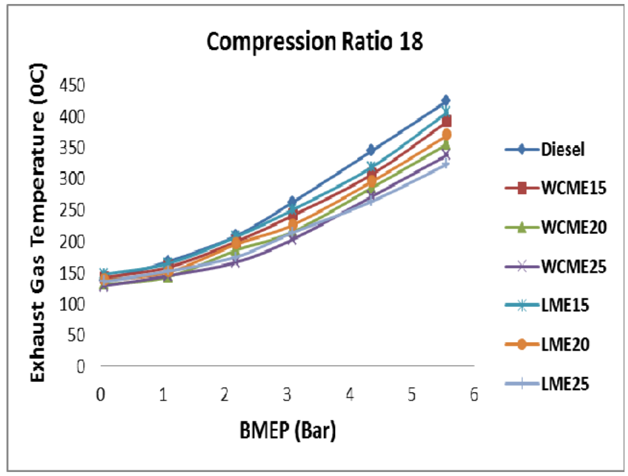

Fig. 6. Variation of egt with brake mean effective pressure at cr 18

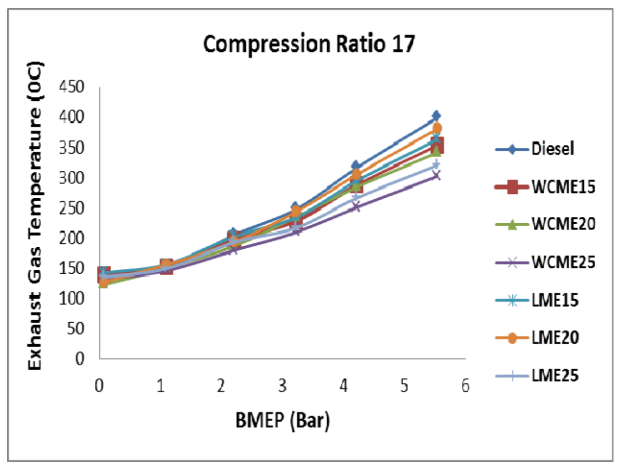

Fig. 7. Variation of egt with brake mean effective pressure at cr 17

While lme20 at cr17 showed highest exhaust gas temperature. It was reported that biodiesel has poor combustion characteristics due to high viscosity which causes higher exhaust gas temperature. The higher exhaust temperature with blends is indication of lower thermal efficiencies of the engine and at lower thermal efficiency, less of the energy input in the fuel is converted to work, thereby increasing exhaust temperature. Results are comparable to those obtained by pramanik k. Et. Al. [24].

4. EMISSION CHARACTERISTICS

Figures (8-13) show the variation of different exhaust emission characteristics viz. HC, CO, CO_2 and NO_X with brake mean effective pressure at compression ratio 18 and 17. All emissions were measured by AVL di gas analyzer. Characteristics of emissions are explained below:

4.1 EMISSION OF UN-BURNT HYDROCARBONS (HC)

It was observed that as load on engine increased, HC emissions are increasing for all fuels and at all compression ratios figures (8-13) . At cr18, wcme15 shows the lowest HC emission that the other fuels. However lme15 exhibited the lowest HC emissions at cr17. The HC emissions were reported 27% for wcme15 and 24% lower for lme15 at cr18 and cr17 respectively at maximum load condition.

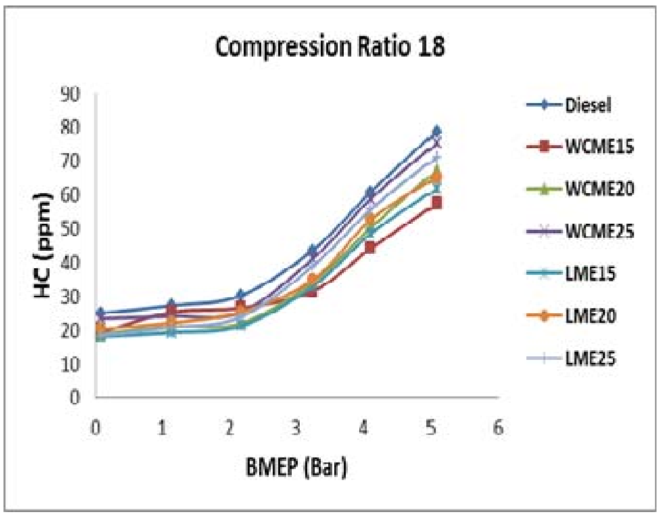

Fig.8: Variation of HC with brake mean effective pressure at cr 18

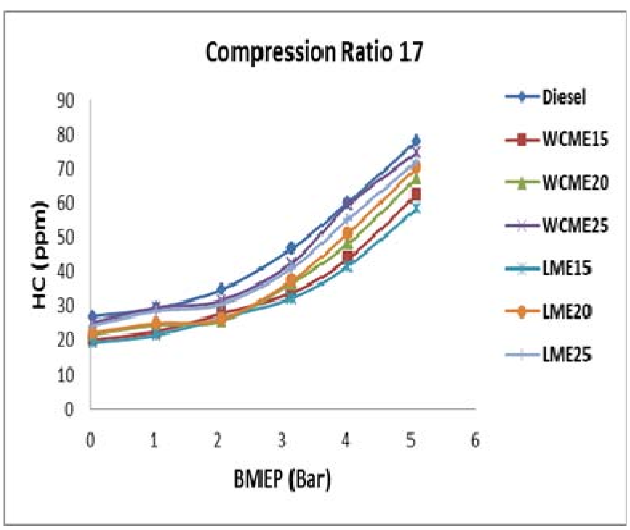

Fig.9: Variation of HC with brake mean effective pressure at cr 17

As we increase the compression ratio combustion enhanced but as the viscosity of the fuel is high hence it affect the combustion phenomenon and leads to incomplete combustion hence the hc emission increases. Also it has been seen that at the part load the variation in the hc emission is insignificant but on increasing the load beyond 60% the combustion affects and hence leads to incomplete combustion. Hc emission is the result of incomplete fuel combustion and it may increase because of excessively rich fuel air mixtures with insufficient oxygen content in the fuel. Consistency of results is verified with results obtained by s. Jindal et. Al.[25].

4.2 EMISSION OF CARBON MONOXIDE (CO)

Emissions of co are explained in figures (10,11). Wcme15 has highest co emission followed by lme15 at both compression ratio. Whereas wcme25 and lme22 have shown significant reduction of co emissions at cr 18 and cr17 respectively when compared to diesel fuel.

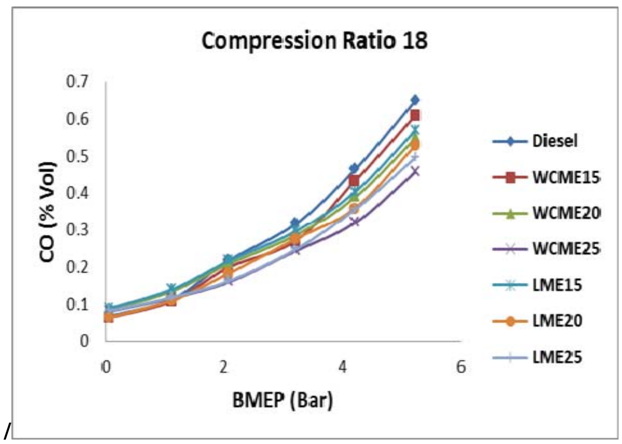

Fig. 10. Variation of CO with brake mean effective pressure at cr 18

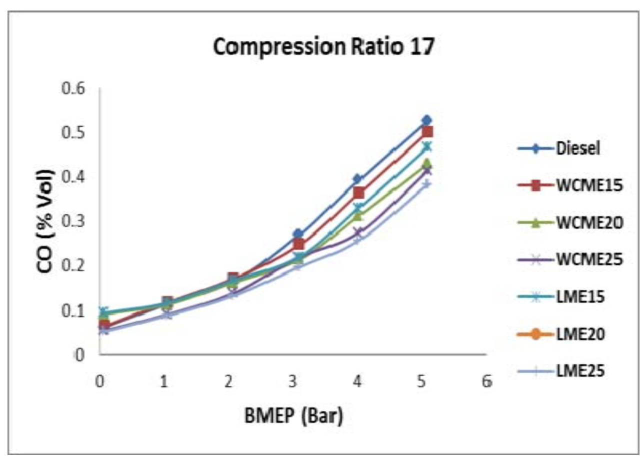

Fig. 11. Variation of CO with brake mean effective pressure at cr 17

With increasing biodiesel percentage, co emission level decreases as amount of oxygen content in biodiesel helps in complete combustion and proper oxidation. The increase in load causes increase in co emissions due to decrease in the air–fuel ratio with increase in load such as all typical internal combustion engines. Results are in agreement with results obtained by kumar ms et. Al.[26].

4.3 EMISSION OF CARBON DIOXIDE (CO_2)

The variation of co_2 with bmep at cr 18 and cr17 for all fuel samples are shown in figures (12,13).results showed substantial reduction in co_2 emission for fuel samples lme15 and wcme15, at cr 18 and cr17 respectively. At cr 18, wcme15 showed 23% reduction in co_2 emission though lme15 indicated 20% reduction respectively at cr17. These results are well confirmed by the results reported by nwafor omi. Et. Al. [27]

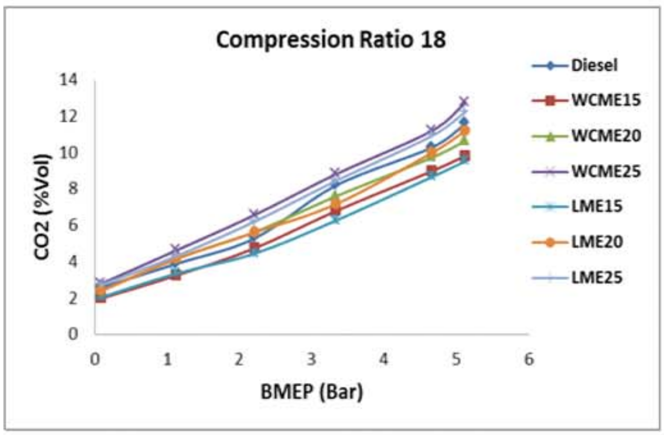

Fig. 12. Variation of CO_2 with brake mean effective pressure at cr 18

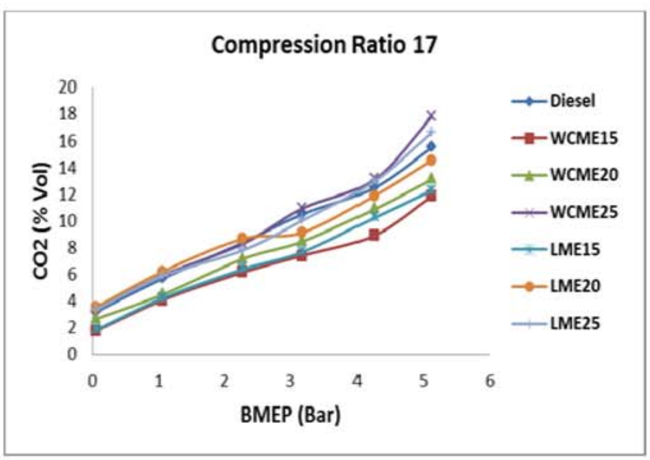

Fig. 13. Variation of CO_2 with brake mean effective pressure at cr 17

4.4 EMISSION OF NO_X

Figures (14,15) show the plots of no_x emissions of the diesel fuel and various fuel samples at cr18 and cr17.it was observed that all fuel samples exhibited higher no_x emissions than that of diesel fuel. However increase in no_x emission was reported maximum for lme25 at cr18 and cr17 at maximum load condition when compared with diesel fuel. This could be attributed to the increased exhaust gas temperatures and the fact that biodiesel had some oxygen content in it which facilitated no_x formation.

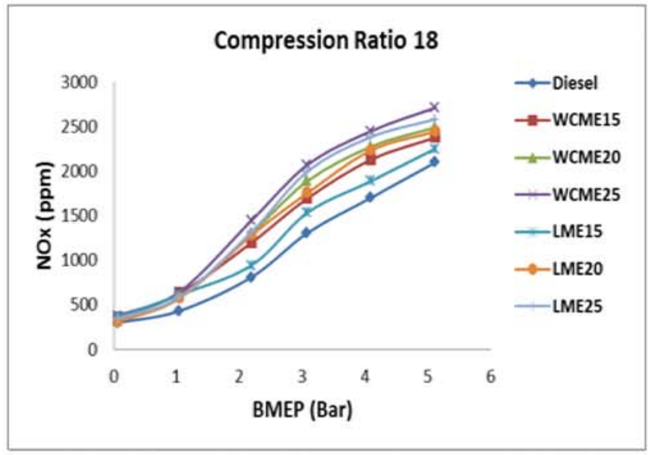

Fig. 14. Variation of NO_X with brake mean effective pressure at cr 18

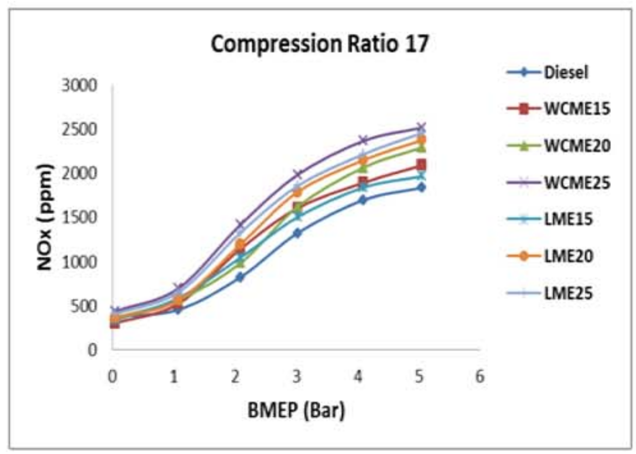

Fig. 15. Variation of NO_X with brake mean effective pressure at cr 17

In general, the NO_X concentration varies linearly with the load of the engine. NO_X emissions are a direct function of engine loads. With increasing load, the temperature of the combustion chamber increases and NO_X formation is enhanced because nox formation is strongly dependent on the temperature. Results are in confirmation with the results obtained by ban-weiss ga. Et. Al [28].

5. CONCLUSIONS

The objective of the present study is to investigate the performance and emissions of a diesel engine operating on waste cooking oil methyl ester and linseed oil methyl ester blends and to compare these results with those operating on neat diesel. Based on the experiment results, the following conclusions may be drawn from the present analysis.

I. It was observed that increase in brake power; caused increase in thermal efficiencies of all the fuels at part load condition but on further increment, bte of all fuels at compression ratio (cr) 18 and cr17 were reported a lower than diesel fuel. At cr 18 and cr 17 lme15 showed bte very close to diesel fuel.

II. At cr 18 and cr17, bsfc for all fuel samples is found to be higher than that of diesel fuel. While at cr 18 and cr17, bsfc for lme25 is close to diesel fuel. Blend wcme15 exhibited highest bsfc at cr 18 and cr 17.

III. The increase in brake power causes increase in exhaust gas temperature for all fuels. At cr18, lme15 showed the highest value of exhaust gas temperature of 406^0c but slightly lower than that of diesel with temperature of 425^0c. Though lowest temperature of 352^0c was obtained for lme 25 and lme20 at cr17 showed highest exhaust gas temperature.

IV. It was examined that as load on engine increased, hc emissions are increasing for all fuels and at all compression ratios. At cr18, wcme15 shows the lowest hc emission that the other fuels. However lme15 exhibited the lowest hc emissions at cr17. The hc emissions were reported 27% for wcme15 and 24% lower for lme15 at cr18 and cr17 respectively at maximum load condition

V. Results showed that wcme15 has highest co emission followed by lme15 at both compression ratio. Whereas wcme25 and lme22 have shown significant reduction of co emissions at cr 18 and cr17 respectively when compared to diesel fuel. Because with increase in biodiesel percentage, co emission level decreases as amount of oxygen content in biodiesel helps in complete combustion and proper oxidation. Results showed substantial reduction in co_2 emission for fuel samples lme15 and wcme15, at cr 18 and cr17 respectively. At cr 18, wcme15 showed 23% reduction in co_2 emission though lme15 indicated 20% reduction respectively at cr17

VI. It was observed that all fuel samples exhibited higher no_x emissions than that of diesel fuel. However increase in no_x emission was reported maximum for lme25 at cr18 and cr17 at maximum load condition when compared with diesel fuel. This could be attributed to the increased exhaust gas temperatures and the fact that biodiesel had some oxygen content in it which facilitated no_x formation.

In general, the performance and exhaust emission results of blends of linseed methyl ester are very much comparable to diesel fuel and could improve engine performance and reduce the exhaust emissions, as well. Henceforth it can be concluded that blends of linseed methyl ester with diesel fuel can be used in the engine without any modification.

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