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MANISH ABHINAV PLAZA-II, ABOVE FEDERAL BANK,
PLOT NO-5, SECTOR-5, DWARKA, NEW DELHI, INDIA-110075,
PHONE: - + (91)-(11)-47026006

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Aims and Scope

Indian Journal of Mechanical and Thermal Engineering is a peer-reviewed journal for the presentation of original contributions and the exchange of knowledge and experience on the sciences of heat transfer and thermodynamics, and contribute to the literature of engineering sciences on the national and international areas but also help the development of mechanical engineering. engineers and academicians from disciplines of power plant engineering, energy engineering, building services engineering, HVAC engineering, solar engineering, Wind engineering, Nano engineering, surface engineering, thin film technologies, and computer aided engineering will be expected to benefit from this journal's conclusions.

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Contents

Search for Ecofriendly Alternatives Refrigerants in Vapour Compression Refrigeration Systems for Reducing Global Warming and Ozone Depletion

R. S. Mishra
Department of Mechanical, Production Industrial and Automobiles Engineering, Delhi Technological University, Delhi, India
e-Mail Address: hod.mechanical.rsm@dtu.ac.in

ABSTRACT

The methods for improving energy and exergetic efficiency have been considered in this paper by using water as secondary coolant in evaporator with nano particles of Al2O3 and TiO2 mixed R718 refrigerant is investigated in this paper. Detailed energy and exergy analysis of multi-evaporators at different temperatures in the vapor compression refrigeration systems have been done in terms of performance parameter for R507a, R125, R134a, R290, R600, R600a, R410a, R407c, R404a and R152a refrigerants. The numerical computations have been carried out for both systems. The use of nano particles improves the energy and exergy performance significantly. The best thermodynamic performance is found using R152a and worst performance is observed using R410a.

Due to flammable nature of R290, R600, R600a and R152a , the R134a is recommended for domestic applications. The results were compared by using water in secondary circuit with nano refrigerants and without nano-particles used and it was found that use of nano-particles improves thermal performances significantly. The energy performance improvement in terms of COP and exergetic performance in terms of exergetic efficiency (rational efficiency) using TiO2 is better than using Al2O3 with R718 refrigerant in the secondary evaporator circuit.

Keywords- Sustainable Development,Performance Improvement, Vapor Compression Refrigeration Systems, Energy and Exergy Analysis, Nano refrigerants

1. INTRODUCTION

In the Make India and Green India Programme, the use of ecofriendly refrigerants is well demonstrated due to global warming and ozone depletion and several training programmes are available for skill development in the various institutions such as SLIT, ITIs, and several polytechnics and various centres in IITs (such as CRT, CES), various technological universities etc.

This paper highlights the use of R-290 refrigerant is the best alternative and second alternative is R600a. and third is R-152a. Due to flammable nature of these ecofriendly refrigerants, these refrigerants can only be used by using safety measures, otherwise R134a and R410a and R404a are easily available in the markets can be used. The performance of R134a gives better than using R410a and R404a, however for larger Industrial applications R 717 and R744 can be used. Even in mixing of nanoparticles mixe of nanoparticles mixed with R718 in the secondary circuit and R1234yf for low temperature applications gives better first law and second law performance as compared to R134a refrigerant .To replace, R134a, R1234yf (of zero ODP and 4 GWP) and R1234ze (GWP=6, and Zero ODP) are recommended, although these refrigerants gives 5 to 10% less performance than using R134a. Although the performance of R134a is better than R134a using nano particles mixing in R718 but R1234ze can replace R134a for higher temperature applications. The best first law and second law performances have been found using copper nano materials mixed with R718 in secondary evaporator circuit as compared to TiO2 nano particles.

2. LITERATURE REVIEW

Mishra et al. [7-9] performed numerical analysis of vapour compression refrigeration system using R134a, R143a, R152a, R404A, R410A, R502 and R507A , and discussed the effect of evaporator temperature, degree of subcooling at condenser outlet, superheating of evaporator outlet, vapour liquid heat exchanger effectiveness and degree of condenser temperature on COP and exergetic efficiency. They reported that evaporator and condenser temperature have significant effect on both COP and exergetic efficiency and also found that R134a has the better performance while R404a has poor performance in all respect. Saravana kumar [10] compared the performance between R134a and R290/R600a mixture on a domestic refrigerator which is originally designed to work with R134a and found that R290/R600a hydrocarbon mixture showed higher COP and exergetic efficiency than R134a. In their analysis ,highest irreversibility obtained in the compressor compare to condenser, expansion valve and evaporator.

Based on the literature it was observed that researchers have gone through detailed first law analysis in terms of coefficient of performance and second law analysis in term of exergetic efficiency of simple vapour compression refrigeration system with single evaporator. Researchers did not go through the irreversibility analysis (second law analysis) of followings:

1. Simple VCR with nano particles used as secondary evaporator circuit in the water cooled evaporator.
2. Detailed analysis of vapour compression refrigeration systems using thirteen ecofriendly refrigerants with effect of nano particles for improving their first and second law performances.

This paper mainly deals with effect of nano particles (TiO2 and Al2O3) mixed with R718 refrigerants was used in the water cooled evaporator for improving thermal performance of vapour compression refrigeration systems for keeping evaporator size constant due to enhancing heat transfer coefficient in the evaporator. The computation modeling of vapor compression refrigeration systems was carried out with the help of EES for first and second law analysis in terms of energetic analysis i.e. COP (First law analysis) and exegetic analysis in terms of exergetic efficiency, exergy destruction ratio (EDR)

In this analysis we assumed negligible pressure losses and heat losses. The comparative performance for condenser temperature varying between 320K to 330K with increment of 2 and evaporator temperature is varying from 265K to 281 K with increment of 4. The energy and exergy change in vapour compression refrigeration cycle have been calculated for various eco friendly refrigerants such asR125, R507, R-134a, R404a, R410a, R407c R-290 (propane), R600 (butane), R-600a (isobutene) for environmental temperature of 298K. and results are shown in Table(1-3) respectively. The performance of vapour compression refrigeration system using ecofriendly refrigerants in the primary circuit and TiO2 nano particles mixed in R718 is used in the secondary circuit of evaporators are shown in Table-(1). to Table-(3) respectively and it was found that maximum First law efficiency in terms of COP and maximum second law efficiency in terms of exergetic efficiency using ecofriendly R152a and minimum first and second law performance using R410a. Due to flammable nature of R152a, and R290, R600 and R600a which can be used by considering safety measure gives better performance. The R407c R134a and R404a also gives good performance for replacing R502, R11 and R12 and R22 which produces global warming and ozone depletion.

Table: 1. Performance prediction of vapour compression refrigeration system using TiO2 in R718 in the secondary circuit and Ecofriendly refrigerants in primary circuit for condenser temperature 48oC and evaporator temperature of -5°C

S.No	Refrigeran	COP OP	ETA_II	EDR
1	R404a	4.36	0.4831	1.694
2	R410a	2.14	0.2396	6.836
3	R134a	4.36	0.4880	1.659
4	R152a	5.169	0.5786	1.143
5	R507a	4.328	0.4844	1.685
6	R407c	4.736	0.5301	1.391
7	R290	4.826	0.5402	1.335
8	R600	3.605	0.4036	2.429
9	R600a	4.009	0.4480	1.969
10	R125	4.03	0.4511	1.949

Table: 2. Variation of performance parameters with condenser temperature in the vapour compression refrigeration system using R-134a in primary circuit and Water in secondary circuit

S.No	Condenser Temp. (°C)	COP	ETA_II	EDR
1	47	2.919	0.3013	0.6987
2	49	2.825	0.2859	0.7141
3	51	2.736	0.2713	0.7287
4	53	2.652	0.2575	0.7425
5	55	2.572	0.2442	0.7558
6	57	2.497	0.2316	0.7684

Table 2 explaining the variation of condenser temperature with first and second law performance parameters and it was observed that increasing condenser temperature reduces first and second law performances and also increases exergy destruction ratio while Table-3shows the variation of [12] evaporator temperature with first and second law performance parameters. and it was found that first law performance in terms of coefficient of performance and second law efficiency increases and exergy destruction ratio of system decreases.

Table: 3. Variation of performance parameters with evaporator temperature in the vapour compression refrigeration system using R-134a in primary circuit and Water in secondary circuit

S.No	Evaporator Temp (°C)	COP	ETA_II	EDR
1	-8	2.481	0.3105	0.7000
2	-4	2.767	0.3000	0.7146
3	0	3.096	0.2854	0.7451
4	8	3.467	0.2649	0.7631
5	12	3.880	0.2369	0.8002

The thermodynamic performance have been obtained using R-152a ecofriendly refrigerant and worst performances were found using R-410a ecofriendly refrigerants. Due to flammable nature of R290, R600 , R600a and R152a it is recommended that R407c and R134a is suitable for industrial and commercial applications.

3. CONCLUSION

In this paper, first law and second law analysis of vapour compression refrigeration systems using multiple evaporators and single compressor and single expansion valve with ecofriendly refrigerants in the system and R718(water used in secondary circuit with and without nano particles mixed with water used as refrigerant) have been presented. The conclusions of the present analysis are summarized below:

1. The First law efficiency (COP) and Second law efficiency (Exergetic efficiency) of vapour compression refrigeration systems using R718 mixed with nano particles gives better performance is than without nano particles used in the secondary circuit of water cooled evaporator for above mentioned ecofriendly refrigerants.

2. The First law efficiency (COP) and Second law efficiency (Exergetic efficiency) of vapour compression refrigeration systems using R152a refrigerant is higher but is has flammable nature similar to hydrocarbons then safety measures to be taken while using R152a or hydrocarbons (R290, R600 and R600a).

3. The first law performance in terms of Coefficient of performance and second law performance in terms of exergetic efficiency improvesusing TiO2 in thesecondary evaporator circuit as compared to Al2O3 in the secondary circuit

4. COP and exergetic efficiency for R507a and R134a are nearly matching the same values.are better than that for R125.

5. For practical applications R-407c, R134a and R404a, R125 can be used recommended because it is easily available in the market has second law efficiency slightly lesser than R-152a which was not applicable for commercial applications due to flammable nature and R717 is also toxic nature.

6. The first law performance improvement in terms of COP and second law performance in terms of exergetic efficiency (rational efficiency) using TiO2 is better than using Al2O3 with R718 refrigerant in the secondary evaporator circuit.

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Solving The Vendor Selection Problem Using Fuzzy Topsıs For Rame -2016

Pravin Kumar[1] and Rajesh Kumar Singh[2]
[1]Department of Mechanical Engineering, Delhi Technological University, Bawana Road, Delhi, e-Mail: pravin.papers@gmail.com

[2]Operations Management, Management Development Institute, Gurgaon, Haryana, e-Mail: rksdce@yahoo.com

A B S T R A C T

The purpose of this paper is to evaluate the vendor under fuzzy environment. Some of the information and data available about the vendors may be vague and imprecise in nature. To deal with the impreciseness in information available fuzzy TOPSIS for vendor evaluation has been used. Linear Programming has been used along with Fuzzy TOPSIS to maximize the total value of purchase in quota allocation process. The important criteria for vendor evaluation have been indentified and Fuzzy TOPSIS technique has been used for vendor evaluation. Finding demonstrates that Fuzzy TOPSIS methodology may be suitable for the vendor in the environment of uncertainty. This paper explores important criteria for vendor evaluation and application of Fuzzy TOPSIS in vendor evaluation process.

Keywords- Vendor Selection, Fuzzy TOPSIS, Multi criteria Decision Making.

1. INTRODUCTION

In the recent years, supply chain management (SCM) has gained immense importance, since enterprises are now competing on supply chain rather than manufacturing or service operations. Supply chain management involves the flows of material, information and money in a network consisting of customers, suppliers, manufacturers, and distributors. A well managed supply chain leads to cost reduction, lead time reduction, on-time delivery and lower inventories. In supply a chain good coordination between supplier and manufacturer is necessary.

Mostly the cost of raw materials and component parts constitutes the main cost of a product. In some cases it can account for up to 70% (Ghodsypour & O'Brien, 1998). Goffin et al. [1] have stated that supplier management is one of the key issues in supply chain management because the cost of raw materials and component parts constitutes the main cost of a product and most of the firms have to spend considerable amount of their sales revenues on purchasing. Therefore it becomes important to have efficient and reliable vendors which lead to cost reduction and maximize the profit. Ghodsypour and O'Brien [2] have stated, selecting a good supplier significantly reduce the purchasing cost and improve corporate competitiveness.

Global competitive environment continues to force many companies to make strategic changes in managing their business. Most of manufacturers have been downsizing, concentrating on their core competencies, moving away from vertical integration, and outsourcing more extensively [1]. In today's competitive operating environment, it is impossible to successfully produce low-cost, high-quality products without full cooperation of vendors [3]. Selection of appropriate vendor is one of the fundamental strategies for enhancing the quality of output in an organization, which has direct influence on the company [4].

Thus vendor selection and evaluation is important part of organizations strategic decisions. But vendor selection is a complex and time-consuming process. Some time the information and data available may not have the accuracy required it may be imprecise in nature. So, to deal with such kind of imprecise data Zadeh developed fuzzy set theory, this can be used to deal the imprecise situations.

According to Fuzzy TOPSIS principle is that the chosen alternative should have the shortest distance from the positive ideal solution and the farthest distance from negative ideal solution. Fuzzy Positive ideal solution (FPIS) is a solution that maximizes the benefit criteria and minimizes cost criteria, whereas the Fuzzy negative ideal solution (FPIN) maximizes the cost criteria and minimizes the benefit criteria.

In rest of the sections we have discussed Vendor selection methodology, numerical illustration, discussion and conclusion.

2. LITERATURE REVIEW

2.1 Vendor Selection Criteria

Vendor selection decisions are an important component of supply chain management for many firms [5]. The analysis of criteria for vendor evaluation has been the focus of many academicians and purchasing practitioners since the 1960s [6].

In his study, Dickson [7] interviewed 273 purchasing agents and managers selected from membership list of National Association of Purchasing Managers, and indentified 23 vendor evaluation criteria and their importance rating. He concluded that critical factors for supplier selections are quality, on time delivery, supplier performance history and warranties and claims got high ranking. Weber et al. [6] reviewed 74 articles for vendor selection and observed that net price, delivery, quality; production facilities, technical capabilities, reputation, financial position and performance history are mostly used criteria. They concluded that quality is most important factor followed by delivery and cost. Wilson [8] found that quality and services are becoming more important compared to price. This shifting is due to JIT and SCM philosophy.

Choi and Hartley [9] explored supplier selection criteria for auto industry. They used the criteria used by Dickson [7] and Weber et al. [6], including some other criteria suggested by researchers. They used 26 criteria and grouped them in to 8 main factors. The eight factors are, Finance (financial condition, profitability of supplier, financial record disclosures and performance awards), Consistency (conformance quality, consistent delivery, quality philosophy and prompt response), Relationship (long term relationship, relation closeness, communication openness and reputation), Flexibility (product volume changes, short setup time, short delivery lead time and conflict resolutions), Technological capability (design capability and technical capability), Services (after sale support and sale representative competences), Reliability (incremental improvement and product reliability) and Price (low initial price). They found that cooperation and long term relationship was most important for vendor selection.

Barbaresoglu and Yazagac [10] used performance, manufacturing capability and quality system for vendor selection. They found that performance assessment is ranked highest followed by quality and capability assessment.

Mandal and Deshmukh [11] used quality, delivery, production facility and capacity, price, financial position, technical capability, management and organization, transport and communication connivances, after sale service and attitude and willingness to support as a important criteria in Indian industry perspective. They concluded that price, delivery and after-sales service are the top-level criteria. Quality, attitude and willingness to do business are the second-level criteria. The remaining criteria are in the lower levels. Shlrouyehzad et al. [4] considered service quality, price, delivery and rate of rejected parts as a vendor selection criteria and found that vendor who have best service quality are not necessarily efficient.

Ho et al. [12] reviewed papers published between 2000 to 2008 on multi-criteria decision making approaches for vendor selection and evaluation. They found that price or cost is not most widely adopted criterion. They observed quality as the most popular criterion used for evaluating the performance of vendor, followed by delivery, price or cost, manufacturing capability, service, management, technology, research and development, finance, flexibility, reputation, relationship, risk, and safety and environment.

There are a number of criteria used for vendor selection, some of important criteria can be explained as:

Cost: The purchasing price is significant to decrease cost and to promote the competitiveness of products for enterprise. Therefore the purchasing price is an important consideration to the purchasing organization [13]. Ho et al. [12] found that cost is third most important criteria used for vendor evaluation.

Quality: Quality is a critical concern for most enterprises. The need for high quality vendors has always been an important issue for enterprises. The factors assessing quality mainly include systems, equipment for manufacturing, products, process capability etc. Ho et al. [12] ranked quality a number one criteria reviewing paper published between 2000- 2008.

Delivery: Along with quality, another factor that is considered a basic prerequisite for vendor selection is punctual delivery. In the selection process, delivery performance has an important criterion [14]. Since Dickson's [7] study conforming to quality specifications and meeting delivery deadlines remain the most important supplier selection criteria. In a fundamental sense, these form the threshold criteria that buying firms apply to all suppliers before they can be considered as strategic partners in the buyer-supplier relationship [9]. According to Choi and Hartley [9] they have emerged as order qualifiers to the extent that if suppliers cannot demonstrate acceptable performance in these two areas, they will be dropped as potential candidates during the screening phase itself. Ho et al. [12] found delivery as the second most important criteria for vendor evaluation.

Flexibility: Flexibility is one of the important objectives in operation strategy model [15] and is often seen as a reaction to environmental uncertainty [16]. Flexibility is described as the ability of a manufacturing system to cope with environmental uncertainties [17]. There are many ways to characterize supply chain flexibility, for example, manufacturing flexibility and marketing flexibility [18]. In general, flexibility reflects an organization's ability to effectively adapt or respond to changes that add value in the customer's eyes[19].

Financial Capability: A solid financial position helps ensure that performance standards and availability of product and services [20]. A vendor on financially unstable footing will have much more difficulty contributing to the partnership venture, as it must focus its efforts on improving its financial soundness. Hence, both suppliers and buyers are becoming more mindful of the financial position of their potential partners in their decision making [21].

Reputation: Reputation is defined as the perception of quality over time. There is definitely a notion of quality, but it may be real today or may be perceived based on past quality or past experience. A positive reputation can lead to trust and confidence development. Wilson [8] argues that "reputation for performance become a measure of trust when partner is untested". Similarly, Michel et al. [22] suggest that reputation is an element of trust because it affects cognitive perception of quality.

2. 2. Vendor Selection Methods

There a number of methods used for vendor selection. Boer et al. [23] presented a review of decision methods reported in the literature for supporting the vendor selection process. They showed that several suitable Operations Research methods such as data envelopment analysis, total cost of ownership approaches, linear programming, linear weighting models, statistical methods and artificial intelligence.

Masella and Rangone [24] proposed the use of the Analytic Hierarchy Process (AHP) to deal with imprecision in supplier choice. Tahriri et al.[25] applied AHP approach for supplier selection and evaluation in steel manufacturing company. Handfield et al. [26] proposed an AHP model that included relevant environmental criteria in supplier selection decision.

Sarkis and Talluri [27] proposed the use of the Analytical Network Process (ANP), a more sophisticated version of AHP, for supplier selection. Mandal and Deshmukh [11] applied Interpretive Structural Modeling(ISM) technique for the supplier selection. It's main goal to indentify and summarize the relationship among items and to form structural model of problem. Min[28] used multi attribute utility approach for international supplier selection.

Karpak et al. [29] used goal programming to minimize costs and maximize quality and delivery reliability when selecting suppliers and allocating orders among them. Weber and Desai [30] propose Data Envelopment Analysis (DEA) for evaluation of vendors that were already selected. Rosenthal et al.[31] developed a Mixed Integer Linear Program (MILP) that would find the purchasing strategy for the buyer to minimize the total purchase cost, and the computational results was also presented on a personal computer with standard optimization software.

Ghodsypour and O'Brien [32] used an integrated AHP and LP model for the vendor selection and order allocation problem. Degraeve and Roodhooft [33] develop a mathematical programming model that minimises the total cost of ownership of the supplier choice and inventory management policy using activity-based costing information. Degraeve et al. [34] extend this methodology to the service sector in developing an airline selection model for the procurement of business travel.

Tempelmeier [35] formulated MILP model for supplier selection and purchase order sizing for a single item under dynamic demand conditions. Dahel [36] presented a multi-objective mixed integer programming approach to simultaneously determine the number of vendors to employ and the order quantities to allocate to these vendors in a multiple-product, multiple-supplier competitive sourcing environment.

Statistical models deal with the stochastic uncertainty related to the vendor choice. Tracey and Tan [37] employed confirmatory factor analysis and path analysis to examine empirically the relationships among supplier selection criteria, supplier involvement on design teams and in continuous improvement programs, customer satisfaction, and overall firm performance.

Choy and Lee [38] presented an intelligent generic supplier management tool using the Case Based Reasoning (CBR) technique for outsourcing to suppliers and automating the decision making process when selecting them.

Wu et al. [39] presented a so-called augmented imprecise DEA for supplier selection. A web-based system was developed to allow potential buyers for supplier evaluation and selection.

Ng [40] developed a weighted linear programming model for the supplier selection problem, with an objective of maximizing the supplier score. Similar to AHP, it involves the decision makers in determining the relative importance weightings of criteria.

Golmohammadi et al. [3] applied neural network model. The managers' judgments about suppliers were simulated by using a pair-wise comparisons matrix for output estimation in the Neural Network (NN). Genetic algorithm (GA) was applied for the initial weights and architecture of the network. Finally supplier is selected.

Singh et al. [41] used fuzzy statistical approach for vendor selection in supply chain. In which integration of standard score (z –value) and linear programming is purposed in integrated form to select the best vendors and placed optimum order quantity among them using fuzzy mathematical approach.

Kumar et al. [42] used fuzzy ELECTRE for green evaluation of the suppliers giving weights to the green practices and the environmental management and control.

3. RSEARCH METHODOLOGY

Vendor selection is multi-criteria decision making problem in which all the information available may not be precise. To deal with impreciseness, fuzzy logic is used extensively. Fuzzy TOPSIS method used for vendors' evaluation and LP is used for quota allocation. The ranking of vendors are incorporated in quota allocation problem.

3.1 Fuzzy Logic

Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than precise. Most real world decision problems take place in a complex environment conflicting systems of logic, uncertain and imprecise knowledge, and possibly vague preferences have to be considered. To face such complexity, the use of specific tools, techniques, and concepts which allow the available information to be represented with the appropriate granularity is believed as crucial. Particularly, fuzzy set theory can ideally cope with this kind of problems.

Fuzzy Numbers: Fuzzy numbers are the special classes of fuzzy quantities. A fuzzy number M represents a generalization of a real number. A fuzzy number M is a convex normalized fuzzy set. A fuzzy number is characterized by a given interval of real numbers, each with a grade of membership between 0 and 1 [43]. A Triangular Fuzzy Number (TFN)
M= (l, m, u) is shown in Figure 1.

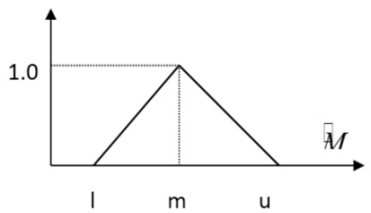

Figure 3.1: A Triangular fuzzy number, $\tilde{M}$

Triangular fuzzy numbers are defined by three real numbers, expressed as (l, m, u). The parameters l, m, and u, respectively, indicate the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event. Their membership functions are described as;

$$\mu(x/\tilde{M}) = \begin{cases} 0, & x < l, \\ (x-l)/(m-l), & l \le x \le m, \\ (u-x)/(u-m), & m \le x \le u, \\ 0, & x > u \end{cases} \qquad (1)$$

In applications it is convenient to work with TFNs because of their computational simplicity, and they are useful in promoting representation and information processing in a fuzzy environment. Mathematical Operations on TFNs: Although we are familiar with algebraic operations with crisp numbers, when we want to use fuzzy sets in applications, we have to deal with fuzzy numbers. We can define various operations on TFNs. But in this section, important operations used in this study are illustrated. If we define, two TFNs A and B by the triplets A= (la, ma, ua) and B= (lb, mb, ub). Then

Addition:

$$A+B= (l_a+ l_b, m_a+ m_b, u_a+ u_b) \quad (2)$$

Subtraction:

$$A-B= (l_a- l_b, m_a - m_b, u_a - u_b) \quad (3)$$

Multiplication:

$$A.B = (l_a, m_a, u_a).(l_b, m_b, u_b) = (l_a l_b, m_a m_b, u_a u_b) \quad (4)$$

Division:

$$A/B = \left(\frac{l_a}{u_b}, \frac{m_a}{m_b}, \frac{u_a}{l_b}\right) \quad (5)$$

Inverse:

$$(l_a, m_a, u_a)^{-1}=(1/u_a, 1/m_a, 1/l_a) \quad (6)$$

Distance B/W Two triangular Fuzzy numbers: Distance between two triangular fuzzy numbers A (l_a, m_a, u_a) and B (l_b, m_b, u_b) can be calculated as follows:

$$d(A,B) = \sqrt{\frac{1}{3}\left[(l_a-l_b)^2+(m_a-m_b)^2+(u_a-u_b)^2\right]} \quad (7)$$

$$d(A,B) \in R^+$$

Distance between two fuzzy numbers is crisp in nature

3. 2. TOPSIS

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method was firstly proposed by Hwang and Yoon [44]. It is very effective in multi-criteria decision-making (MCDM). The basic concept of this method is that the chosen alternative should have the shortest distance from the positive ideal solution and the farthest distance from negative ideal solution. Positive ideal solution is a solution that maximizes the benefit criteria and minimizes cost criteria, whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria.

The TOPSIS method assumes that each criterion has a tendency of monotonically increasing or decreasing utility. Therefore, it is easy to define the ideal and negative ideal solutions. The Euclidean distance approach was proposed to evaluate the relative closeness of the alternatives to the ideal solution. Thus, the preference order of the alternatives can be derived by a series of comparison of these relative distances.

Fuzzy TOPSIS: In the classical TOPSIS method, the weights of the criteria and the ratings of alternatives are known precisely and crisp values are used in the evaluation process. However, under many conditions crisp data are inadequate to model real-life decision problems. Therefore, the fuzzy TOPSIS method is proposed where the weights of criteria and ratings of alternatives are evaluated by linguistic variables represented by fuzzy numbers to deal with the deficiency in the traditional TOPSIS.

The TOPSIS method is a linear weighting technique, which was first proposed, in its crisp version by Chen and Hwang [45], with reference to Hwang and Yoon [44]). Since then, this method has been widely adopted to solve MCDM problems in many different fields, ranging from robot design [46] to materials selection [47], from the evaluation of performance of competitive companies [48], to the assessment of service quality in airline industry [49].

There are many applications of fuzzy TOPSIS in the literature. For instance,Yong [50] used fuzzy TOPSIS method for plant location selection. Wang and Elhag [51] proposed a fuzzy TOPSIS method based on alpha level sets and presented a nonlinear programming solution procedure for bridge risk assessment. Wang and Chang [52] developed an evaluation approach based on the fuzzy TOPSIS to help the Air Force Academy in Taiwan to choose initial training aircraft. Wang and Lee [53] generalized TOPSIS to fuzzy multiple-criteria group decision-making in a fuzzy environment. They proposed two operators Up and Low that are employed to find ideal and negative ideal solutions.

Semih et.al [54] used a combined model of fuzzy AHP and fuzzy TOPSIS model for selecting shopping centre site in Istanbul. Sun and Lin [55] used fuzzy TOPSIS method for evaluating the competitive advantage shopping websites and selecting the best alternate based on 12 different criteria.

In this paper, the extension of TOPSIS method is considered which was proposed by Chen [56] and Chen and Hwang [57] the algorithm of this method can be described as follows:

Step 1: First of all a team of decision-makers team has been formed having 'k' decision makers are asked to rate the vendors against the criteria on linguistic scale. The linguistic rating is converted in to numerical scale using Table 1

Table 1: Linguistic variable for importance of weight of each criterion

Linguistic variable	Triangular fuzzy numbers
Very Low (VL)	(0.0, 0.1, 0.2)
Low (L)	(0.1, 0.2, 0.3)
Medium (M)	(0.2, 0.3, 0.4)
High (H)	(0.3, 0.4, 0.5)
Very High (VH)	(0.4, 0.5, 0.5)

Step 2: Then evaluation criteria are determined.

Step 3: After that, appropriate linguistic variables are chosen for evaluating criteria and alternatives.

Step 4: Then the weight of criteria and performance rating of each vendors (as in decision making unit, DMU) are averaged as shown below:

$$\tilde{w}_j = \frac{1}{k}\sum_{K=1}^{k} \tilde{w}_{jk} \qquad (8)$$

Where $\tilde{w}_j$ is fuzzy weight of criteria j

$\tilde{x}_{ij}$ is the fuzzy rating of vendor 'i' with respect to criteria 'j'

$\tilde{w}_j$ and $\tilde{x}_{ij}$ are average fuzzy weight of criteria and performance rating of ith vendors against jth criteria respectively.

Step 5: Construct the fuzzy decision matrix with m alternatives, n criteria and k decision makers

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \end{array}$$

Where $\tilde{D}$ represent fuzzy decision matrix with alternative Ai and criteria C_j , $\tilde{x}_{ij}$ (triangular fuzzy no.) represents judgment given by 'k' no. of experts.

i=1, 2…………..m,

j=1, 2………..n

Step 6: Normalize the decision matrix

The aim of normalization is twofold: on the one hand, normalization is necessary to compare heterogeneous criteria, on the other, normalization ensures that triangular fuzzy numbers all range within the interval [0, 1].In the normalization process, different equations have to be applied to benefit criteria and to cost criteria. The following formulae are used respectively:

$$\tilde{r}_{ij} = \frac{\tilde{x}ij}{u_j^+} = \left(\frac{l_{xij}}{u_j^+}; \frac{m_{xij}}{u_j^+}; \frac{u_{xij}}{u_j^+} \right) j \in B \qquad (10)$$

$$\tilde{r}_{ij} = \frac{l_j^-}{\tilde{x}ij} = \left(\frac{l_j^-}{u_{ij}}; \frac{l_j^-}{m_{ij}}; \frac{l_j^-}{l_{ij}} \right) j \in C \qquad (11)$$

$$u_j^+ = \max(u_{xij}) \forall_i = 1, ..., m \in B$$

$$l_j^- = \min(l_{xij}) \forall_i = 1, ..., m \in C$$

Where B represents benefit criteria and C represents cost criteria

The normalization of fuzzy decision matrix is denoted by $\tilde{\tilde{R}}$ shown as the following formula
$\tilde{\tilde{R}}$= [rij] m*n , i = 1; 2; . . . ; m; j = 1; 2; . . . ; n

$$\tilde{R} = \begin{vmatrix} r_{11} & r_{1j} & r_{1n} \\ r_{i1} & r_{ij} & r_{in} \\ r_{m1} & r_{mj} & r_{mn} \end{vmatrix}$$

Where r_{ij} element of normalized decision matrix, i represents the alternative and j represents the criteria.

Step 7: Considering the weight for each criterion, the weighted normalized decision matrix is computed by multiplying the importance weights of evaluation criteria and the values in the normalized fuzzy decision matrix. The weighted normalized decision matrix $\tilde{V}$ is defined as:

$$\tilde{V} = \left[r_{ij} \right]_{m \times n} \times \left[w_j \right] \qquad (12)$$

i= 1,2......m; j= 1,2.......n

$$\tilde{V} = \begin{vmatrix} v_{11} & v_{1j} & v_{1n} \\ v_{i1} & v_{ij} & v_{in} \\ v_{m1} & v_{mj} & v_{mn} \end{vmatrix}$$

In this matrix, each element v_{ij} is a fuzzy normalized number which ranges within the interval [0, 1].

Step 8: This step is aimed at determining the fuzzy positive ideal solution A^+ and the fuzzy negative ideal solution A^-.We know that after normalization each element $\tilde{V}_{ij}$ of fuzzy weight normalized matrix is in the rang [0,1]. Then we can define fuzzy positive ideal solution A^+ and the fuzzy negative ideal solution A^- by following formula:-

$A^+ = (v_1^+; v_2+........v_n+)$ where j= 1,…….,n, is the no. of criteria (13)
$A^- = (v_1^-;v_2^-..........v_n^-)$ (14)

Where v_j^+=max of v_{ij} for B and v_j^+ min of v_{ij} for C

v_j^-=min of v_{ij} for B and v_j^- max of v_{ij} for C

$$v_j^+ = \begin{cases} (1,1,1)\, j \in B \\ (0,0,0)\, j \in C \end{cases}$$

$$v_j^- = \begin{cases} (0,0,0)\, j \in B \\ (1,1,1)\, j \in C \end{cases}$$

Step 9: In this step, the n-dimensional separation distances of each alternative i =1,. . . m to the fuzzy positive ideal solution A^+ and to the fuzzy negative ideal solution A^- are computed.

$$d_{i+} = \sqrt{\sum_{i=1}^{m} d(v_{ij} - v_j^+)^2} \quad (15)$$

$$d_{i-} = \sqrt{\sum_{i=1}^{m} d(v_{ij} - v_j^-)^2} \quad (16)$$

Where d_{i+} and d_{i-} are the separation distances from fuzzy positive ideal situation and fuzzy negative solution respectively.

Step 10**:** In this step each alternatives closeness index is calculated by following formula

$$C_i = \frac{d_{i-}}{d_{i-} + d_{i+}} \quad (17)$$

$$C_i \in [0,1]$$

C_i is closeness index

7. Numerical Illustration

In order to demonstrate the use of fuzzy TOPSIS methodology in vendors' selection an industrial case has been discussed in this paper. Two wheelers manufacturing company ABC located in India is considered as case company. The company is leader in supplying auto component to various auto manufacturing companies. Its present employee strength is 850 (approx). It makes production for both domestic as well as international market.

The company needs to select vendor for disk brakes for a model of a vehicle. There are a large number of vendors who supplies disk brakes, so company wants to evaluate best suited vendors for its operation. Company management believes that consideration of some key criteria in vendor evaluation will increase its efficiency and reduce the cost. But due to limited capacity of the single vendor can't fulfill all the demand of company.

After preliminary screening five vendors are selected for further analysis .Now Company has to evaluate these five shortlisted vendors. For confidentiality we will name those companies as A1, A2, A3, A4 and A5.

A panel of experts as decision-makers is formed. These experts were concerned with purchasing activities.The panel of expert was instructed about the fundamentals of approximate reasoning, fuzzy logic, and the TOPSIS methodology to be adopted. Specifically, the panel acknowledge about the efficacy of the results provided by TOPSIS in terms of relative distances from positive and negative ideal solutions. The project team agreed that the selection criteria to be used were those illustrated in the "The vendor selection criteria" paragraph. First of all, linguistic scales were set to assess both the relative importance of criteria and the performance of each candidate for each criterion. The scales and related fuzzy triangular numbers are shown in Table 1 and 2 respectively.

Table 2: Fuzzy rating of vendors

Linguistic variable	Triangular fuzzy numbers
Poor (P)	(0.0, 0.1, 0.2)
Fair (F)	(0.1, 0.2, 0.3)
Good (G)	(0.2, 0.3, 0.4)
Very Good (VG)	(0.3, 0.4, 0.5)
Excellent (E)	(0.4, 0.5, 0.5)

The three Decision Makers (DM) were then separately asked to judge the importance of each selection criterion. Weights given by each DM, together with pooled fuzzy values are summarized in Table 3 and Table 4

The same panel was separately asked to express verbal opinions about candidate performance against each selection criterion. The results are shown in Table 6. The aggregate weight of criteria rating is calculated.

Step 1: In the first step, a panel of three experts from the case company was selected considering long experience and important role in management of company. They are denoted here D1, D2 and D3 respectively.

Step 2: The important criteria used for vendor evaluation are indentified based on literature. The six important criteria used are

- Cost
- Quality
- Delivery
- Flexibility
- Financial capability
- Reputation

They are denoted by C1, C2, C3, C4, C4, C5 and C6 respectively.

Step 3: Three decision makers asked to weight the criteria according to the provided linguistic variable as per Table 1.

Step 4: The weight of criteria and performance rating of each vendors are aggregated using equations 8 and 9 respectively. The result is shown in Table 4 and Table 5 respectively

Table 3: Fuzzy weight importance given by three decision makers

Criteria	D1	D2	D3
C1	H	H	VH
C2	VH	VH	VH
C3	VH	H	VH
C4	H	VH	H
C5	H	H	H
C6	M	H	M

Step 5: Normalizing the fuzzy decision matrix according to equation (10) and (11) for benefit and cost functions in criteria, the normalized decision matrix is given in Table 6.

Step 6: Incorporating the different weight of each criterion, the weighted normalized decision matrix is computed by multiplying the importance vendor rating of evaluation criteria and the values in the normalized fuzzy decision matrix respectively. This is shown in Table 7.

Table 4: Aggregated fuzzy weights for criteria

Criteria	Aggregated weight
C1	(0.333,0.433,0.500)
C2	(0.400,0.500,0500)
C3	(0.367,0.467,0.500)
C4	(0.333,0.433,0.500)
C5	(0.300,0.400,0.500)
C6	(0.233,0.333,0.433)

Table 5: Aggregated rating of vendors (fuzzy decision matrix)

	A1	**A2**	**A3**	**A4**	**A5**
C1	(0.333,0.433,0.500)	(0.367,0.467,0.500)	(0.233,0.333,0.433)	(0.333,0.433,0.500)	(0.300,0.400,0.500)
C2	(0.133,0.233,0.333)	(0.400,0.500,0.500)	(0.367,0.467,0.500)	(0.267,0.367,0.467)	(0.300,0.400,0.467)
C3	(0.267,0.367,0.467)	(0.367,0.467,0.500)	(0.267,0.367,0.467)	(0.400,0.500,0.500)	(0.200,0.300,0.400)
C4	(0.367,0.467,0.500)	(0.367,0.467,0.500)	(0.200,0.300,0.400)	(0.367,0.467,0.500)	(0.200,0.300,0.400)
C5	(0.300,0.400,0.500)	(0.400,0.500,0.500)	(0.267,0.367,0.467)	(0.300,0.400,0.467)	(0.367,0.467,0.500)
C6	0.267,0.367,0.467)	(0.267,0.367,0.467)	(0.367,0.467,0.500)	(0.267,0.367,0.467)	(0.333,0.433,0.467)

Table 6: Normalized decision matrix

	A1	**A2**	**A3**	**A4**	**A5**
C1	(0.466,0.538,0.700)	(0.466,0.499,0.635)	(0.538,0.700,1.000)	(0.466,0.538,0.738)	(0.466,0.583,0.777)
C2	(0.266,0.466,0.666)	(0.800,1.000,1.000)	(0.734,0.934,1.000)	(0.534,0.734,0.934)	(0.600,0.800,0.934)
C3	(0.534,0.734,0.934)	(0.734,0.934,1.000)	(0.534,0.734,0.934)	(0.800,1.000,1.000)	(0.400,0.600,0.800)
C4	(0.734,0.934,1.000)	(0.734,0.934,1.000)	(0.400,0.600,0.800)	(0.734,0.934,1.000)	(0.400,0.600,0.800)
C5	(0.600,0.800,1.000)	(0.800,1.000,1.000)	(0.534,0.734,0.934)	(0.600,0.800,0.934)	(0.734,0.934,1.000)
C6	(0.534,0.734,0.934)	(0.534,0.734,0.934)	(0.734,0.934,1.000)	(0.534,0.734,0.934)	(0.666,0.866,0.934)

Table 7: Weighted normalized fuzzy decision matrix

	A1	**A2**	**A3**	**A4**	**A5**
C1	(0.155,0.233,0.350)	(0.155,0.216,0.318)	(0.179,0.303,0.500)	(0.155,0.233,0.369)	(0.155,0.233,0.389)
C2	(0.106,0.233,0.333)	(0.320,0.500,0.500)	(0.294,0.467,0.500)	(0.214,0.367,0.467)	(0.240,0.400,0.467)
C3	(0.196,0.343,0.467)	(0.269,0.436,0.500)	(0.196,0.343,0.467)	(0.294,0.467,0.500)	(0.147,0.280,0.400)
C4	(0.244,0.404,0.500)	(0.244,0.404,0.500)	(0.133,0.260,0.400)	(0.244,0.404,0.500)	(0.133,0.260,0.400)
C5	(0.180,0.320,0.500)	(0.240,0.400,0.500)	(0.160,0.294,0.467)	(0.180,0.320,0.467)	(0.220,0.374,0.500)
C6	(0.124,0.244,0.404)	(0.124,0.244,0.404)	(0.171,0.311,0.433)	(0.124,0.244,0.404)	(0.155,0.288,0.404)

Step 7: This step is aimed at determining the fuzzy positive ideal solution A^+ and the fuzzy negative ideal solution A^-. The value of normalized fuzzy decision matrix is in the range within the interval [0, 1].which is 1 for positive ideal situation and 0 for negative ideal situation. This is

A^+= [(1, 1, 1)] for B, [(0, 0, 0)] for C

A^-= [(0, 0, 0)] for B, [(1, 1, 1)] for C

Where B is benefit and C is cost criteria

Step 8: In this step, the n-dimensional separation distances of each alternative i =1, . . . , m to the fuzzy Positive Ideal Solution d_{i+} and to the fuzzy Negative Ideal Solution d_{i-} are computed according to equation (15) and (16), shown in Table 8.

Step 9: In this step each alternatives closeness index is calculated by following formula

$$C_i = \frac{d_{i-}}{d_{i-} + d_{i+}}$$

$$C_i \in [0,1]$$

The optimal alternative have value closeness index closer to 1. According to the closeness coefficient, the ranking of the alternatives can be determined as shown in Table 8.

Table 8: Closeness coefficient and ranking

	di+	di-	Ci	Rank
A1	3.774	2.390	0.387	5
A2	3.417	2.708	0.442	1
A3	3.765	2.410	0.390	3
A4	3.578	2.569	0.418	2
A5	3.762	2.390	0.388	4

Now vendors are rated according to value of closeness coefficient. In table 5.10 vendor A2 has value of closeness coefficient much nearer to 1, so it is ranked first while the value of closeness coefficient for A1 is farthest from 1, so it is ranked last. In this way all other vendors also ranked according to value of their closeness coefficients.

8. RESULT AND DİSCUSSİON

Now from Table10 we can see that vendor A2 is ranked 1st while vendor A1 is ranked 5^{th}. As per fuzzy TOPSIS methodology the vendor having value of closeness coefficient nearest to 1 is ranked 1 while vendor having closeness coefficient farthest from 1 is ranked as fifth. In table 10 value of closeness coefficient of A2 is 0.442, which is highest, so vendor is ranked 1^{st} while A1 have value 0.387 which is lowest, so it ranked last. In this way all other vendors also ranked according to their closeness coefficient.

9. CONCLUSION

Vendor selection is a fuzzy multi criteria decision making problem. To make decision in uncertain condition use of Fuzzy TOPSIS methodology has been demonstrated to evaluate and rank the vendors. In a decision making process, the use of linguistic variables in decision problems is highly beneficial when performance values cannot be expressed in crisp terms.

In this paper, some of the important criteria for vendor evaluation are indentified namely, cost, quality, delivery, flexibility, financial capability and reputation. Fuzzy weights for criteria and performance rating of alternative is done on the basis of linguistic variable as done in fuzzy problems. Then fuzzy

TOPSIS methodology has been applied to select best alternative and rank the various alternatives. Fuzzy TOPSIS method is very flexible. The closeness coefficients not only rank the alternatives but also give the assessment status of all the possible suppliers. Significantly, the proposed method provides objective information for supplier selection and evaluation in a supply chain system.

The systematic framework for supplier selection in a fuzzy environment presented in this work can be easily extended to the analysis of other management decision problems. However, improving the approach for solving supplier selection problems more efficiently and developing a group decision support system in a fuzzy environment can be considered as a topic for future research.

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Performance Analysis of Biogas Run Dual- Fueled Diesel Engine

S.Lalhriatpuia[1] Kunal Kumar Bose[2] Diwakar Gurung[3]
[1]ME Dept., Delhi Technological University, sactrix777@gmail.com
[2]ME Dept., IIT Madras , kunalbose07@gmail.com
[3]ME Dept., NIT Rourkela , diwakargurung007@gmail.com

A B S T R A C T

In this work a systematic experimental investigation is carried out for the performance of the biogas run compression ignition diesel engine in dual fuel mode. Many Experiments were conducted in a modified engine test unit to run biogas under dual fuel operations. For an equal power output from each of the diesel and dual fuel engine operation, the performance results were evaluated. This type of comparison approach can decide the feasibility of a dual fuel engine usage in place of a conventional diesel engine.

Keywords- Biogas, dual fuel engine

1. INTRODUCTION

One of the most serious problems that the world is being confronted is the use of limited fossil fuel like petrol, diesel etc. which has severely harm the environment. So these days' alternatives to this fossil fuel so-called renewable source of energy has been a topic of investigation for researchers. Among the many different available energy sources Biogas from anaerobic digestion of animal manure waste can be used and has proved to meet the demand of environment concern [1]. Biogas may be characterized based on its chemical composition and physical characteristics, which result from it. It is primarily mixture of methane (CH4) and inert carbonic gas (CO2). However, the name "biogas" gathers large variety of gasses resulting from specific treatment processes, starting from different organic wastes like industries, animal or domestic origin waste etc. Earlier Biogas was used for cooking in the rural household but it can be also used for generating shaft power and electricity. Biogas has variety of combustion and compositional characteristics compared to natural gas, so it needs a different system of preconditions compared to the combustion of natural gas [2]. One way of using this biogas can be duel fueled compression ignition diesel engine. The basic concept behind this type of engine is the use of primary fuel also known as gaseous fuel and pilot fuel. The duel fuel engines are classified into two categories depending on the utilization of pilot and gaseous fuel. one category includes the injection of small amounts of liquid fuel to provide ignition to a lean mixture of gas and air. Here the bulk of energy comes from the gaseous fuel (also called primary fuel). And another one is associated with the addition of some gaseous fuel to air in a fully operational diesel engine. The interest of this paper lies within the second category of the dual fueled engine. Earlier there was obscurity about the feasibility of the engine to be run by biogas but the compression of biogas is possible and the application of biogas as a fuel for dual fuel diesel-biogas engines is feasible and economical (Cheng-qiu et al.,1989). An investigation on small biogas/diesel dual-fuel engine for on-farm electricity generation and it was found that the, dueled fuel operation in diesel engine showed superior efficiency compared to normal diesel operation (N. Tippayawong et al.,2007).The gas engine tests for the energy utilization was concluded for the development of experimental variants useful for improvement of biogas produced from pig manure and plant additives and establish the satisfied condition for running the heat engine properly (Attila Meggyes et al.,2012). It was found that found that a small addition of O2 to intake combustion air improve combustion stability in a biogas-diesel engine. The additional O2 helps to attenuate negative effects of CO2 in combustion such as decreases in overall gas-air mixture temperature and low burning velocities of biogas regarding methane (Cacua et al.,2009).

Considering the above literature review it is found that the researchers have done marvelous development in the context of combustion characteristics, improvement of energy utilization, quality improvement of biogas and designing of engine parameter for power output. The present study deals with the study of the performance of dual fuel compression ignition diesel engine which is run by biogas. Here the biogas will be added to the air in a fully operational diesel engine. Initially, baseline performance tests are carried out with the engine operating on diesel fuel only and then with biogas. The main objective is to compare the performance of dual fuel compression ignition diesel engine with a normal diesel engine in terms of brake power, brake power efficiency, volumetric efficiency, exhaust temperature and air consumption.

2. Experimental

2.1 Biogas and Pilot Fuel

Biogas which has been employed as the gaseous fuel mixed with the air for the dual fuel operation. biogas was collected from the Gobar gas plant, Yupia, Naharlagun, Arunachal Pradesh, India. It was produced by the anaerobic digestion of cow manure. In our investigation, the standard diesel is used as the pilot fuel for the experimental work for both baseline and dual fuel mode. This diesel is supplied through the injection pump from the fuel tank under the gravity fed.

2.2 Engine test rig set-up and procedure

The engine used for the investigation is the Petter AA1 Diesel Engine. It is a single cylinder constant-speed, four-stroke, direct injection, water-cooled diesel engine. The rated power is 2.6kW at 3600 min-1 and it has a bore of 70mm and stroke of 57mm. It is designed conventional fuel injection system and loaded with a hydraulic dynamometer. The injection nozzle has three holes of 0.3mm diameter with a spray angle of 120°. The liquid fuels are supplied to the engine injection pump from a fuel tank under gravity feed. Type K thermocouples are installed on different locations of engine setup and connected to a data logger for measuring various temperatures. The airflow to the engine was monitored by passing the intake air through an air box with orifice meter and manometer. The pressure drop was measured by an inclined tube manometer, calibrated in millimeters of diluted ethyl alcohol. The air flow was calculated from the viscous Flowmeter calibration. During the dual fuel operation, Biogas was supplied through a plastic pipe and mixed with inlet air in simple mixing chamber consists of a T-junction of a tube or flow channel(fig.1) with an inlet for air and for gasses each and an outlet for the mixture of both. The outlet is connected to the intake channel or manifold of the engine. the flow rate of Biogas was measured in the Biogas Flowmeter. figure.2 shows the schematic view of dual fuel engine and the connection between various components.

Table 1 . Characteristics of Diesel, Biogas, Manometry fluid and Air used

	Low heat value	Density
Biogas	5000 $kcalm^{-3}$	-
Diesel	44.80 MJ kg^{-1}	820 kg m^{-3}
Diluted ethyl alcohol	-	789 kg/m^3
Air	-	1.225 kg/m^3 at NTP

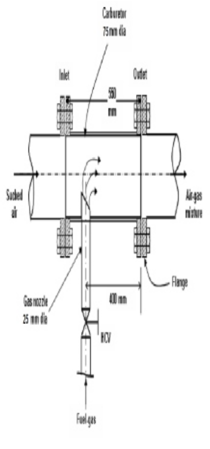

Fig 1. - T-joint tube type mixer

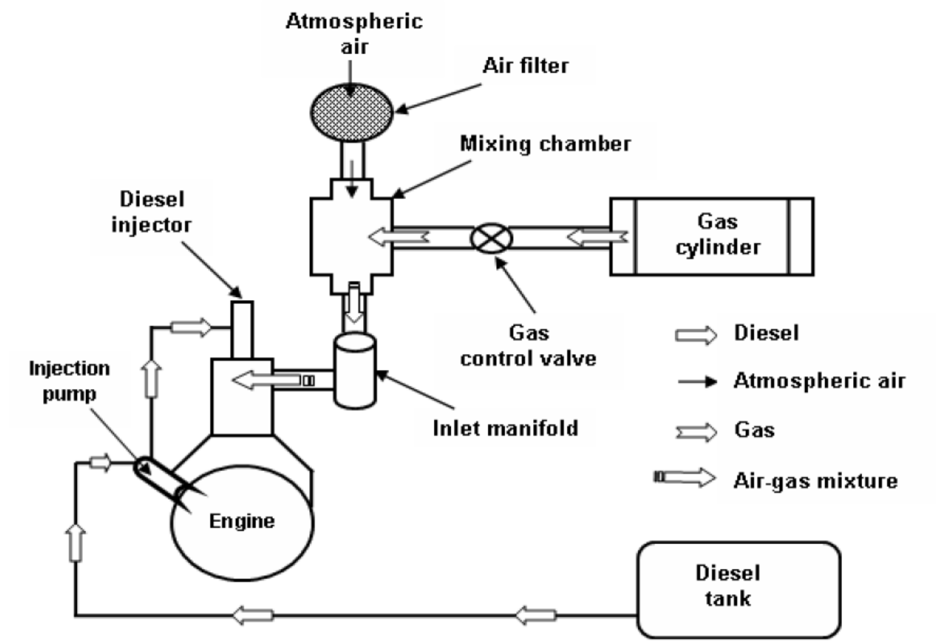

Fig2. - Schematic Diagram of Dual Fuel Diesel Engine

Initially, the engine was run idly at 1500 rpm without any load to reach stable operating conditions for 20 minutes. To establish a basis for comparison of results baseline performance tests was carried out with the engine operating on diesel fuel only. The load was varied in steps from 1.5N to 4N in the hydraulic dynamometer. For each load all the required parameters like rpm, exhaust temperature, the difference in the liquid level of the manometer, Volume of diesel fuel consumption by the engine in one minute etc. are noted. For the biogas dual fuel mode operation, biogas flow was opened up slowly from the gas balloon and allowed biogas to reach the gas carburetor. The homogeneous air-gas mixture from carburetor was hence sucked into the cylinder to take part in the dual fuel combustion via engine manifold. During the process, engine speed was increased due to addition extra chemical energy from biogas. To maintain a constant speed for both diesel and dual fuel modes, the quantity of diesel was varied by adjusting the liquid fuel cut-off valve. The data acquisition was undertaken similar to baseline tests for each step load.

To present the air consumption measured in kghr-1 and volumetric efficiency the following expression is adopted

$$\text{Air flow rate, } F = C_d \times \frac{\pi}{4} \times d^2 \times \sqrt{\frac{2gh \times W_{den}}{A_{den}}} \times 3600 \times A_{den}$$

where C_d is discharged coefficient, d is the diameter of orifice meter in millimetre, h is the height of manometer fluid (diluted ethyl alcohol) in millimetre, A_{den} and w_{den} is the air and manometer fluid density respectively in kgm^{-3}.

$$\text{Volumetric efficiency, } \eta_V = \frac{F}{(\pi/4) \times D^2 \times L \times \frac{N}{n} \times 60 \times K \times A_{den}} \times 100$$

Where D is the diameter of cylinder in millimeter, L is the stroke length of cylinder in millimeter, N is the speed in revolution per minute, K is the number of cylinder andn=1(for Two stroke engine), =2(for four stroke engine) .

The brake power and brake thermal efficiency are calculated according to

$$\text{Brake Power, BP}=\frac{2\times3.142\times N\times W\times R}{60\times1000}$$

$$\text{Mass flow rate of diesel in kghr}^{-1},\ m_d=(X\times60\times\rho_{Lf}/10^6)$$

Where, X is the cc liquid fuel consumption of engine in cc/min) and ρ_{Lf} is the liquid fuel density in kg.m^{-3} Thermal brake efficiency,

$$\eta_{bth}=\frac{BP\times3600}{\dot{m}_d\times LHV_d}\times100 \quad \text{for normal diesel operation,}$$

$$\eta_{bth}=\frac{BP}{\dot{m}_d\times LHV_d+\dot{m}_g\times LHV_g}\times100 \quad \text{for dual fuel operation}$$

Where, LHV_d Low heating value of diesel and $LHV_{g\ is}$ Low heating value of biogas in MJ.kg^{-1}

All these performance parameters were obtained from the above relation and compared the performance of the dual fuel compression ignition diesel engine and normal compression diesel engine. During the process, the serious attention was given for the proper functioning of each component during the experiments.

3. RESULTS AND DISCUSSION

The results of the experiments conducted for the comparison of dual fuel compression ignition diesel engine with normal compression diesel engine are shown in figs 3,4,5 and 6. The patterns of variation for each parameter are found to be almost same. Fig.3 shows the greater air consumption for diesel mode than dual mode at equal loading conditions. more substitution of air takes place by fuel at higher load. Fig.4 shows lower volumetric efficiencies for dual fuel operations than diesel mode. The higher temperature of the retained exhaust gas preheats the incoming fresh air and lowers the volumetric efficiency and at higher power outputs higher biogas substitution displaces a greater proportion of air. The brake power and the brake thermal efficiency obtained for diesel were more than that for dual fuel mode as shown in figure 5 and 6. A considerable reduction in thermal efficiency (about 19% to 40%) was observed under dual fuel modes as compared to diesel mode for the entire load range. This is mainly due to the lower heating value of biogas and by increasing the quality of biogas giving the higher heating value may increase the efficiency to greater extend. Lastly, fig.7 shows the Variation of Exhaust

Load	A/F	VEF %	BRAKE POWER Kw	BTE %	EXHAUST TEMP.(^{0}C)
0.5	5.60	0.69	0.06	0.58	162
1.5	6.00	0.69	0.17	1.69	163
2	4.10	0.69	0.22	1.78	165
2.5	3.59	0.68	0.28	2.01	166
3	2.94	0.67	0.33	2.06	167
3.5	3.23	0.66	0.389	2.68	168
4	2.92	0.66	0.41	2.82	169

Table 2. Experimental observations and performance parameters for diesel

Table 3. Experimental observations and performance parameters for dual

LOAD	A/F	VEF %	BRAKE POWE R kW	BTE %	EXHAU ST TEMP.(^{0} C)
1.5	33.19	85.94	0.30	10.68	197
2	25.78	82.97	0.38	12.03	198
2.5	24.33	81.63	0.32	9.89	200
3	21.20	80.14	0.35	10.24	201
3.5	17.66	80.59	0.41	10.91	202
4	16.03	79.36	0.50	12.30	202

Temperature in which the temperature for dual mode was less than diesel mode.

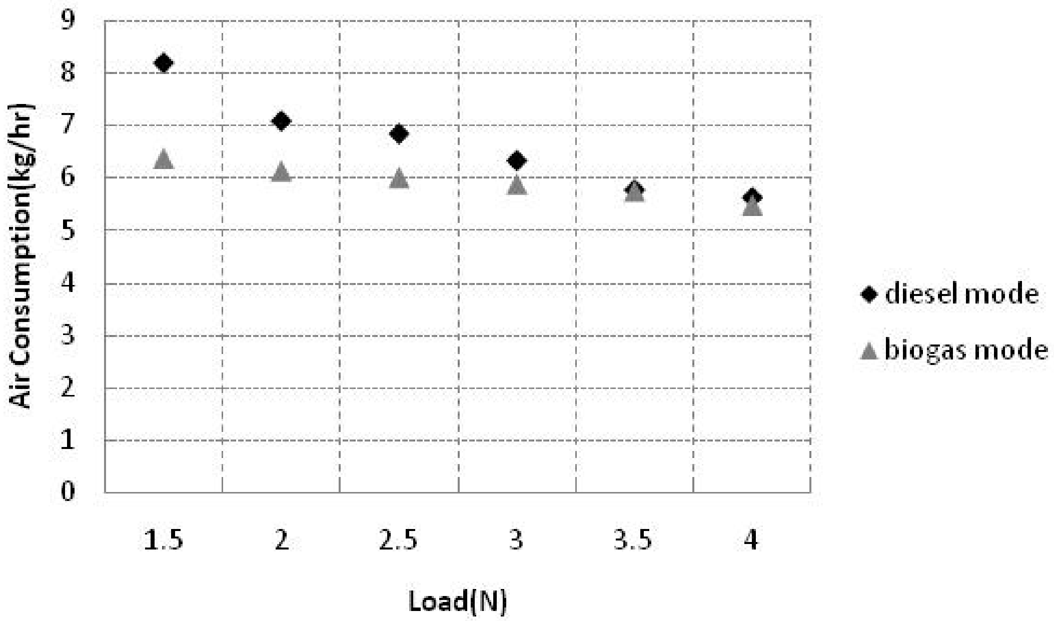

Fig3. Variation of air consumption rate with load from diesel and duel fuel operation

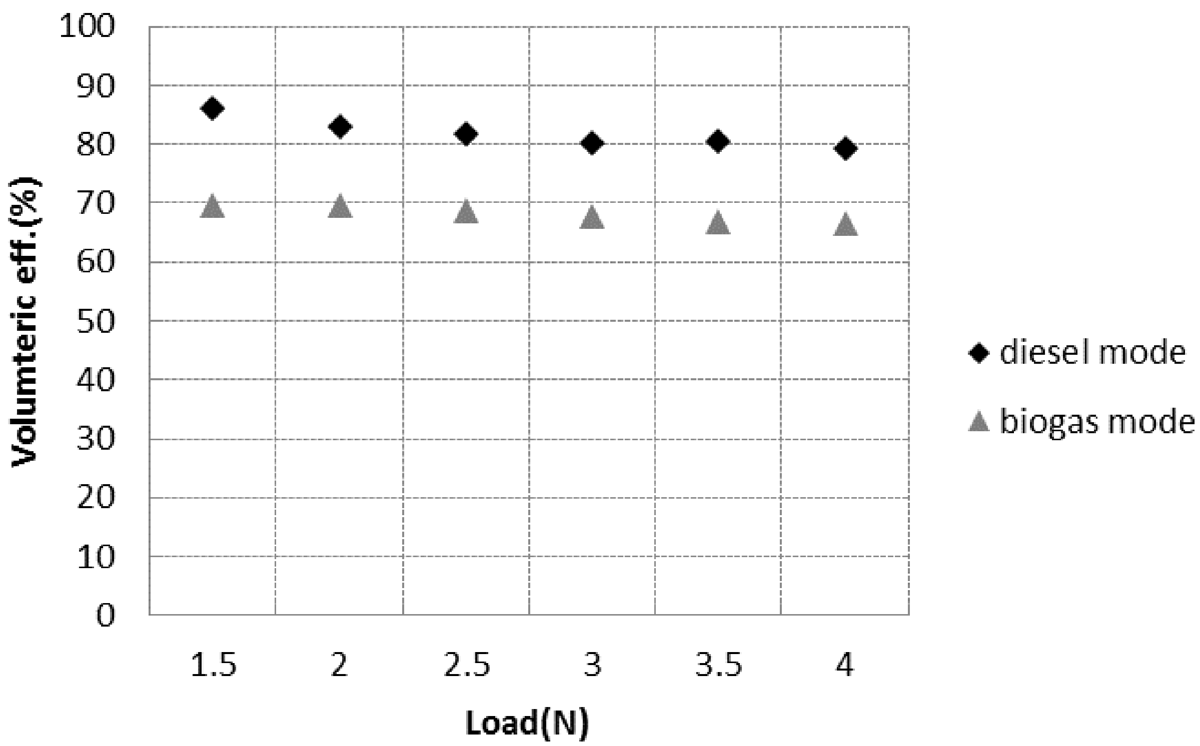

Fig 4. Variation of volumetric efficiency with load from diesel and duel fuel operation

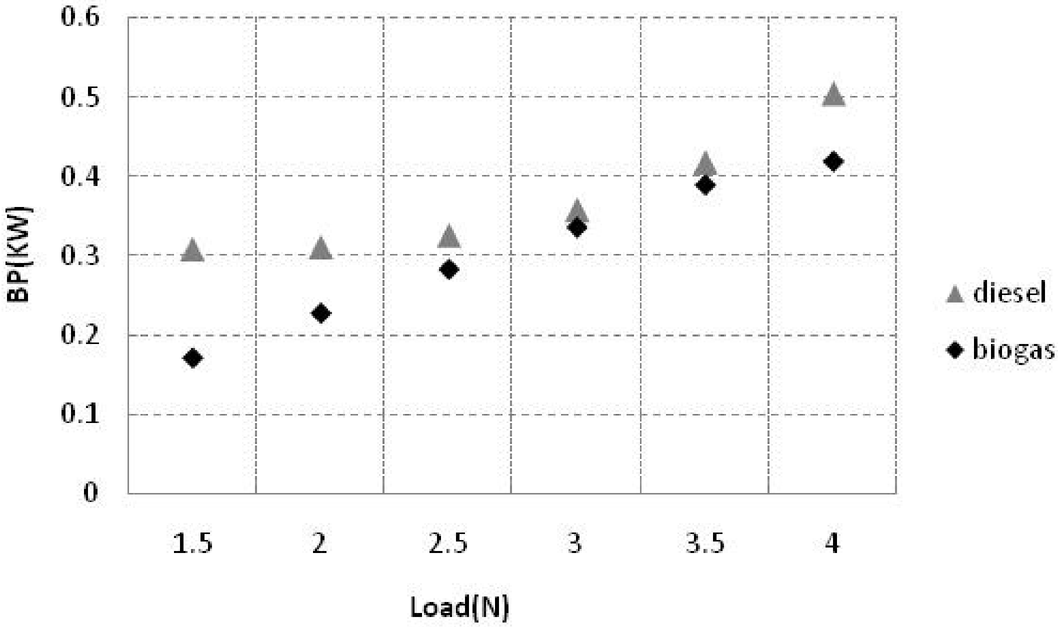

Fig5. Variation of brake power with load from diesel and duel fuel operation

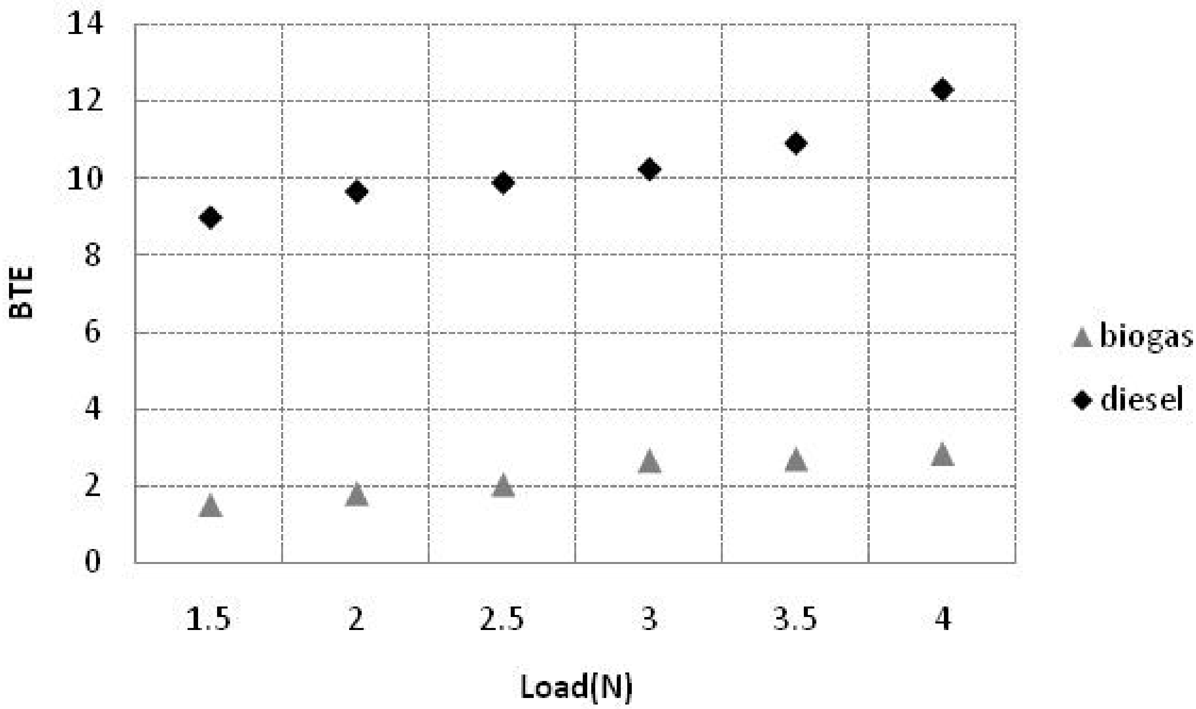

Fig6. Variation of brake thermal efficiency with load from diesel and duel fuel operation

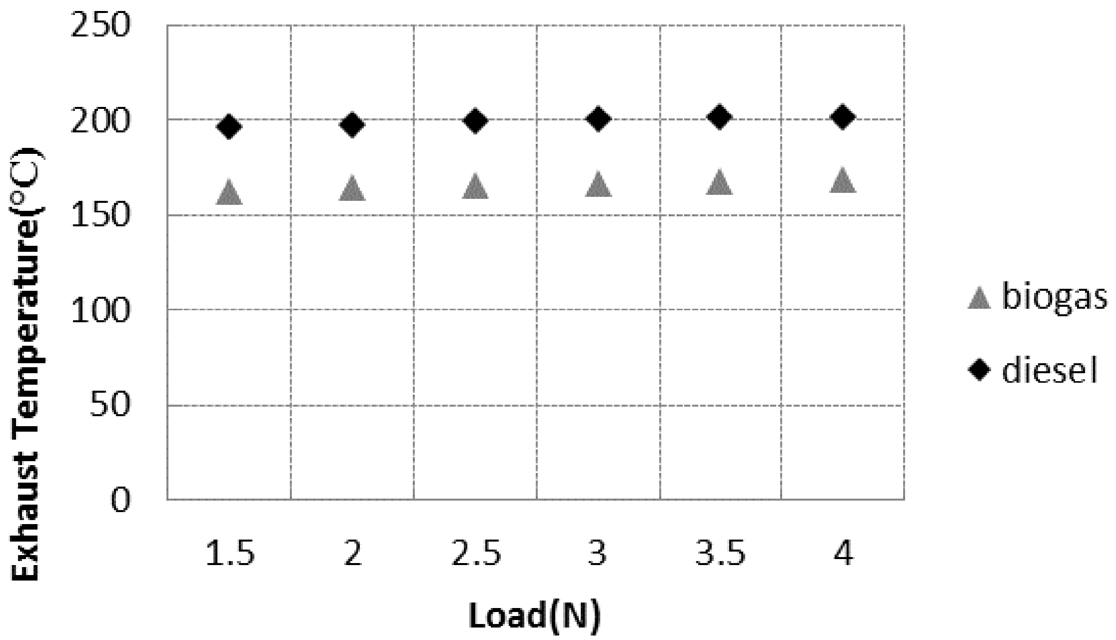

Fig7.Variation of exhaust temperature with load from diesel and duel fuel operation

4. CONCLUSION

Diesel engines are established as a unique combination of energy efficiency, power, reliability, and durability. They play a vital role in transport sectors, farm and construction purpose, power generation, etc. But these engines adopt fossil diesel fuel-based technology which contributes to the production of greenhouse gasses by CO and CO_2 emissions. In order to reduce these carbon emissions, there are possible and available clean diesel technologies viz., alternative fuels, hybrid-electric power and fuel cell etc. Use of clean gaseous fuel like biogas, alternative to diesel, is one of the techniques which have the potential for reducing greenhouse gas emissions. dual fuel compression ignition diesel engine can be used for obtaining power from biogas. In the present work, an experimental investigation has been carried out to evaluate the various performance parameters of dual fuel compression ignition diesel engine compared it with the normal diesel engine. There was an increase in brake power and brake thermal efficiency with a load for both diesel and dual fuel mode. The brake power for diesel mode was greater than dual fuel mode. The maximum brake power obtained for diesel mode was 0.50kW at 4N load, for dual fuel mode was 0.41kW at 4N load. thermal efficiency obtained for diesel mode was 12% at 4N load and for dual mode was 2.82% at 4N load. Use of biogas having higher heating valve can increase the brake power and the brake thermal efficiency of the dual fuel engine. This indicates the adoption of this biogas may reduce the diesel fuel cost which causes higher CO and CO2 emissions. Although the power obtained through the dual fuel compression ignition diesel engine was found to be less in the experiment conducted but this dual-fuel engine appeared to perform well and have great potential for producing power and also meet the criteria of environment concern.

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Performance Analysis of CI Engines Using Biodiesel-Diesel Blends

Shashank Mohan[‡], Amit Pal and RS Mishra
[1] Department of Mechanical Engineering,
Delhi Technological University, Bawana Road, Delhi-110042.
shashank20mohan@gmail.com
[‡] Corresponding Author; Tel: +91 8285177272

A B S T R A C T

Methods for reduction in global warming using bio-diesel blends in single cylinder compression ignition engine has been investigated in terms of the quantity and quality of energy. In our study the first and second Laws of thermodynamics are employed to analyze the quantity and quality of energy in a single cylinder, direct injection diesel engine using conventional diesel fuel and biodiesel fuel. Performance and emissions have been calculated for each fuel operation and compared with each other. Performance tests are also conducted for equivalence air–fuel ratio, fuel consumption, volumetric efficiency, brake thermal efficiency, brake power, and brake specific fuel consumption, while exhaust emissions are analyzed for carbon monoxide (CO), carbon dioxide and unburned hydrocarbons (HC), using diesel and biodiesel blends with different percentages of fuel at three-fourth throttle opening position for variable brake power in a VCR Engine

Keywords: Biodiesel, Transesterification, Opacity, Brake Specific Fuel Consumption, Brake Thermal Energy

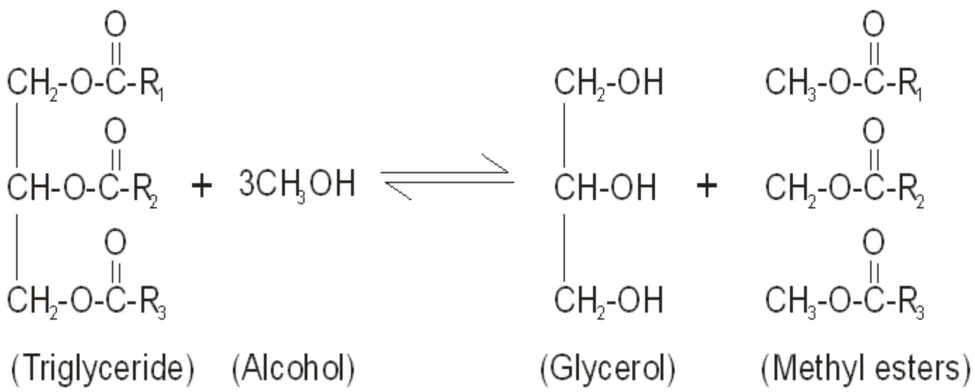
1. Introduction

The petroleum fuels play a very important role in the development of industrial growth, transportation, agricultural sector and to meet many other basic human needs. The increasing energy demand, reducing harmful emissions, and depletion of fossil fuel resources inevitably necessitate for the optimum utilization of exhaustible fossil fuel and non-renewable energy resources. Hence, the scientists are looking for alternative fuels and biodiesel is one of the best available sources to fulfill the energy demand of the world. There are several factors that need to be taken care before recommending any alternate fuel to be used with existing technologies on a large scale. The main factors are stated below:-

1. Extent of modification required in existing hardwares, i.e., if any alternate fuel needs extensive modification in the existing hardware involving huge capital investment, then it may be difficult to implement.
2. The investment cost for developing infrastructure to manufacture and supply of these alternate fuels. The excessive infrastructure cost may act as a deterrent to the development of the alternate energy resources.

3. Environmental compatibility as compared to conventional fuels.
4. Additional cost to the user in terms of routine maintenance, equipment wear and lubricating oil life. The excessive additional cost will have an adverse effect on the widespread acceptance of alternate fuels

Biodiesel has high potential to gradually replace petroleum based fuels as they satisfy most of the parameters mentioned above. Biodiesel is a sulfur-free, non-toxic, biodegradable and oxygenated fuel with a higher cetane number and lubricity. Although vegetable oils hold promise as alternative fuels [4, 5], using raw oils in diesel engines can lead to problems like injector coking and piston ring sticking. Hence raw oils are converted into more suitable form called Biodiesel. Biodiesel are the alkyl esters produced from triglycerides present in naturally occurring fats and oils by transesterification with alcohol, usually methanol, in the presence of a catalyst. Transesterification involves a reaction between immiscible alcohol and triglycerides to form glycerol and esters in the presence of catalyst as shown in equation 1. The reaction is reversible and hence excess alcohol is required to shift the equilibrium to the product side.



(1)

Many researchers [5, 7-16], have studied biodiesel fuels and their blends with petroleum diesel fuel as an alternative energy source in the compression ignition engine, and its performance, emissions and combustion characteristics of the engine were analyzed. The results showed that biodiesel fuels provided increase in brake specific fuel consumption (Bsfc) since biodiesel fuels have lower heating values. Based on these studies, biodiesel can be used as a substitute for diesel in diesel engine.

Considerable research has been carried out for Thermodynamic analysis of CI engines for using Biodiesel blend [1-3, 6]. Biodiesel blend has not been used majorly till now and it has a great scope in India. Research is being carried out to make Biodiesel economically viable for transportation purposes. Increase of biodiesel percentage in biodiesel blends would help in preventing unsustainable usage of natural resources. Biodiesel usage results in lower emissions of toxic compounds. NOx emission increases whereas Hydrocarbon emissions decrease with Biodiesel. Cetane number of Biodiesel is more than normal diesel. This paper deals with energetic and exegetic analysis of CI engine using higher percentage of biodiesel blend, optimization of engine performance using higher percentage of biodiesel blend irreversibility associated with various processes of CI engine.

2. Material and Methods

Cottonseed oil is extracted from the seeds of cotton plant of various species, mainly Gossypium hirsutum and Gossypium herbaceum. Cotton grown for oil extraction is one of the big four genetically modified crops grown around the world, next to soy, corn, and rapeseed. Refined CSO is composed predominantly of oleic acid. Oleic acid is an $C_{18:1}$ unsaturated fatty acid. Gossypol is a toxic yellow polyphenolic compound produced by cotton and other members of the order Malvaceae, such as okra. This coloured compound is found in tiny glands in the seeds, leaf, stem, tap root bark and root of the cotton plant. CSO used in this work was purchased from a local market of Madhya Pradesh where cotton is cultivated in abundance. Diesel (D-100) was purchased from nearby Indian oil Corporation Petrol Pump.

This project is carried out in two stages: preparation of biodiesel from cottonseed oil and testing for performance of VCR diesel engine using B20 and B40 and B60 Biodiesel-Diesel blends.

Energy Analysis

Most transient-flow processes can be modelled as a uniform flow process. With the purpose of simplifying the first law calculations of the test engine, the following assumptions were made; the engine operates at steady-state, the whole engine, including the dynamometer, is selected as a control volume, the combustion air and the exhaust gas each forms ideal gas mixtures and potential and kinetic energy effects of the incoming and outgoing fluid streams are ignored. After these assumptions, fuel energy rate to the control volume is given by the following equation

$$\dot{Q}_f = \dot{m}_f \cdot LHV$$

where LHV is the lower heating value (kJ/kg) and mf is the mass flow rate of fuel (kg/s), respectively.

Power of the engine are determined by Equation P_e=V.I/1000 (KW)
After that, brake specific fuel consumption, (bsfc) can be calculated by following relation.

$$bsfc = \frac{\dot{m}_f}{P_e} \cdot 3600 \quad (g/(kW \cdot h))$$

Total exhaust heat, the overall heat in the exhaust gases expressed as a rate of energy flow is given by

$$\dot{Q}_{ex} = \frac{\dot{m}_{gw} C_{p,w} \left(T_{w2} - T_{w1}\right)}{\left(T_{e2} - T_{e3}\right)} \cdot \left(T_{e1} - T_{0}\right)$$

where; m_{gw} : mass flow rate of calorimeter cooling water (kg/s); Cp,w : specific heat of the calorimeter cooling water (kJ/kgK); Tw1: cooling water inlet temperature (°C); Tw2: cooling water outlet temperature(°C); Te1: Exhaust gas temperature at engine(°C); Te2: Exhaust gas temperature at inlet to calorimeter (°C);

Te3:exhaust gas temperature at outlet from calorimeter (°C);

T0: ambient air temperature (°C) [26,34].Total heat loss to be consisting of cooling water and radiation heat is determined by Eq.(2). Thermal efficiency of the control volume (energy percentage), is usually determined as the ratio of the power output (net work) to the fuel energy input and determined by Eq.(3).

$$\dot{Q}_{thl} = \dot{Q}_f - (P_e + \dot{Q}_{ex})$$

$$\eta_{th} = \frac{\text{Useful output}}{\text{Energy Input (Fuel's Heating Value)}} = \frac{P_e}{\dot{Q}_f} = \frac{P_e}{\dot{m}_f \cdot LHV}$$

Exergy Analysis

Unlike energy, the value of exergy depends on the state of the environment as well as the state of the system. Therefore, exergy is a combination property. The exergy analysis of thermal systems is performed to improve energy source utilization by determining the order of exergy destructions and losses in the processes and components of the system and then by reducing them. In principle, four different type of exergy can be identified. These are denoted, respectively, as kinetic, potential, physical and chemical exergy, viz.: The specific flow exergy of a fluid stream (e) is obtained from this sum, Eq. (4). However, exergy is the sum of the thermo mechanical and chemical exergies. tme and che are thermo mechanical and chemical exergies, respectively. Thermo mechanical exergy is defined as Eq.(5)

$$e = e_{Pot} + e_{kin} + e_{phy} + e_{ch} \quad = e_{tm} + e_{ch}$$

$$e_{tm} = h - h_o - T_o \cdot \left(s - s_o\right)$$

Where h and s are flow enthalpy and flow entropy per unit mass at the relevant temperature and pressure, respectively, while h_0 and s_0 stand for the corresponding values of these properties when the fluid comes to equilibrium with the reference environment. The specific chemical exergies of liquid fuels can be evaluated from the following expression on a unit mass basis

$$e_f^{ch} = \left[1.0401 + 0.1728\frac{h}{c} + 0.0432\frac{o}{c} + 0.2169\frac{s}{c}\left(1 - 2.0628\frac{h}{c}\right)\right] \cdot |LHV|$$

h, c, o, and s are the mass fractions of H, C, O, and S, respectively. Chemical exergies of diesel fuel (C16H34), and biodiesel (C18.74H34.43O2) were computed using this equation, and the values are presented in Table

Table 1. Elemental analysis of No.2 diesel fuel and biodiesel [6].

Elements	Number 2 Diesel	Biodiesel
h/c	0.14657	0.15317
o/c	-	0.14228
s/c	0.00047	0.000064

And finaly, exergy rate balance relation is given by Eq. (6)

$$\underbrace{\sum_s (1-\frac{T_o}{T})\dot{Q}_{cv}}_{\text{Exergy transfer by heat}} - \underbrace{\dot{W}_{cv}}_{\text{Exergy transfer by work}} + \underbrace{\sum_{in} \dot{m}\cdot e - \sum_{out} \dot{m}\cdot e}_{\text{Exergy transfer by mass}} - \dot{E}_{destroyed} = \Delta\dot{E}_{system}$$

and

$$\dot{E}_d = T_o S_{gen}$$

T indicates the absolute temperature at the location on the boundary where the heat transfer occurs. When computing the rate of exergy transfer accompanying heat transfer, it was assumed that Qcvis rejected into the ambient air from the boundary having the same temperature as the engine coolant exiting the engine block. Inserting values for the exergy transfers accompanying heat, mass flow, and power transfers, the rate of exergy destruction in the engine can be determined by the Eq. (7)..

$$\dot{E}_f = \dot{m}_f \cdot e_f^{ch} \quad \text{(Fuel exergy)} \qquad \dot{E}_Q = \sum_s (1-\frac{T_o}{T})\dot{Q} \quad \text{(Heat exergy)} \qquad \dot{E}_w = \dot{W} = P_e \quad \text{(Work exergy)}$$

3. Experimental Work

3.1 Preparation of Cottonseed oil Methyl Esters (CSOME)

The cottonseed oil was filtered thoroughly twice to remove any suspended impurities. It is then heated at 110-120^0 C to remove any moisture content. Free Fatty Acid Content of the. In order to find FFA content, 10 gm of Isopropyl alcohol is added to the oil with 2 drops of phenolphthalein. It is then poured into a burette and then titrated with N/10 solution of NaOH. In our experiment 0.1 ml of NaOH was required. The FFA content of the acid is calculated by the formula : (5.61 X Volume used)/2. Since the FFA content of the Cottonseed oil comes out to be less than 1.5 we can go for straight transesterification of the oil. Methanol (20 % by volume of oil) and KOH (1% by weight of oil) are thoroughly mixed till they get completely dissolved to form potassium Metha-Oxide. Cottonseed oil is then mixed with Potassium Methaoxide while the mechanical heating and stirring is going on at about 65 ◦C for 1.5 hours. Glycerin is formed at the bottom layer CSOME floats above it after the mixture is allowed to settle for 2 hrs. Raw Biodiesel is then collected and is Water Degummed and/or Acid Degummed to bring the Phosphorous content to 250/25 ppm respectively. Thereafter, biodiesel is repeatedly washed with water at 35-40 ◦C. Finally, the biodiesel is heated to 120 ◦C to remove any excess water.

3.2 Preparation of CSOME and diesel Oil Blend

The CSOME was properly filtered with a diesel engine fuel filter and then blended with diesel oil in varying proportions with the intention of reducing its viscosity close to that of the diesel fuel. Engine test experiments are performed with different diesel-CSOME blends. All these blends were stable under normal conditions.

3.3 Experimental Set Up for Performance Testing

Fig: 1 Experimental setup

The setup consists of a single cylinder, four strokes, Diesel engine connected to eddy current type dynamometer for loading. It is used with necessary instruments for combustion pressure and crank-angle measurements. These signals are interfaced to a computer through engine indicator for P-θ & P-V diagrams. Sensors are used interfacing airflow, fuel flow, temperatures and load measurement. The setup has standalone panel box consisting of air box, two fuel tanks for duel fuel test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rotameters are provided for cooling water and calorimeter water flow measurement. The engine specifications are given in Table 3. The setup enables varying the compression ratio for measurement of engine performance parameters like BTE, brake specific fuel consumption (BSFC). Lab view based

Engine performance analysis software package "Engine soft LV" is used for on line performance evaluation. A computerized diesel injection pressure sensor is used for the measurement of combustion chamber pressure.

5. Results and Discussions

Fig. 2 to 10 shows performance characteristics at variable load conditions at different compression ratios for neat diesel and diesel-CSOME blends (B-20, B-40 and B-60).

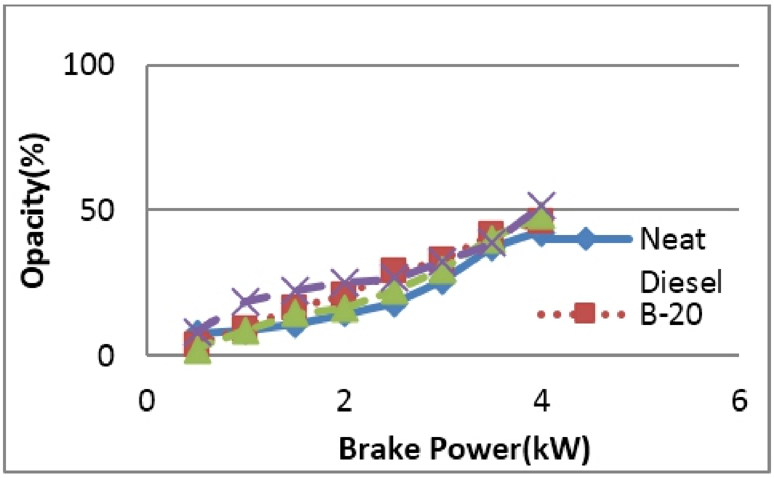


Fig.2 : Comparison of Opacity v/s Brake Power for diesel and CSOME blends at 16 CR

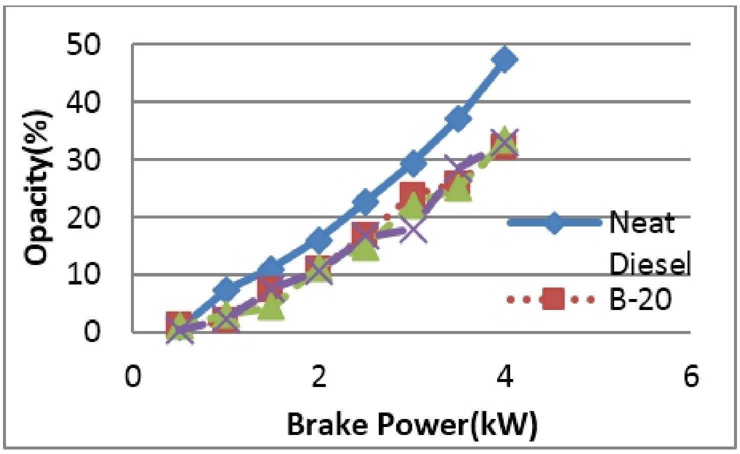


Fig.3 : Comparison of Opacity v/s Brake Power for diesel and CSOME blends at 18 CR

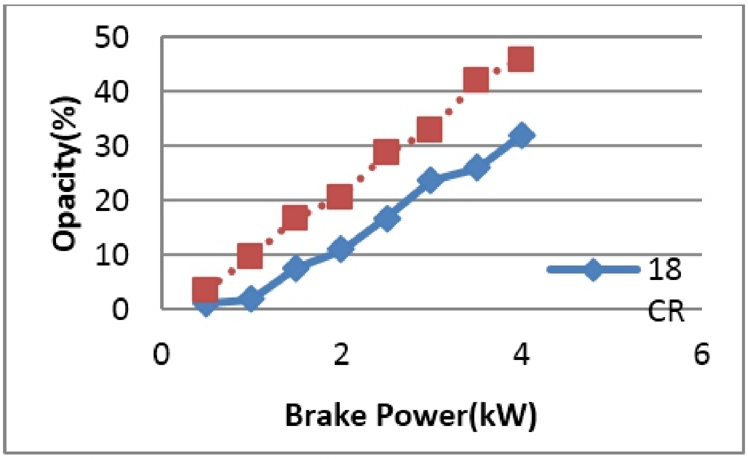


Fig.4 : Comparison of Opacity v/s Brake Power for B-20 at different compression ratios

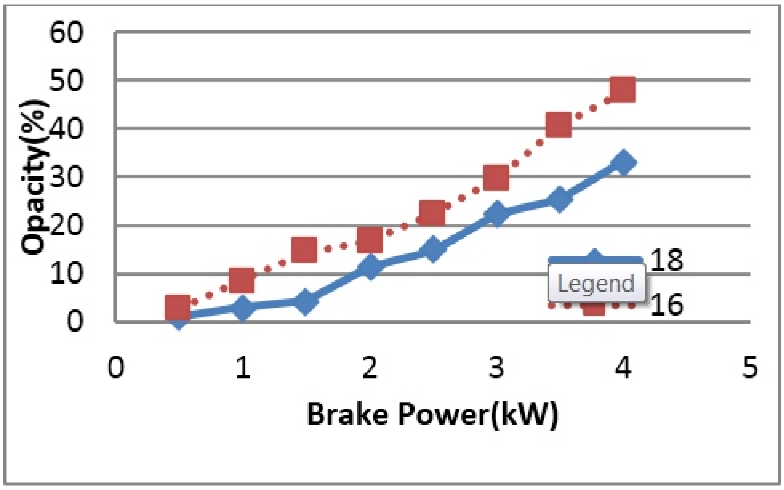


Fig.5 : Comparison of Opacity v/s Brake Power for B-40 at variable compression ratio

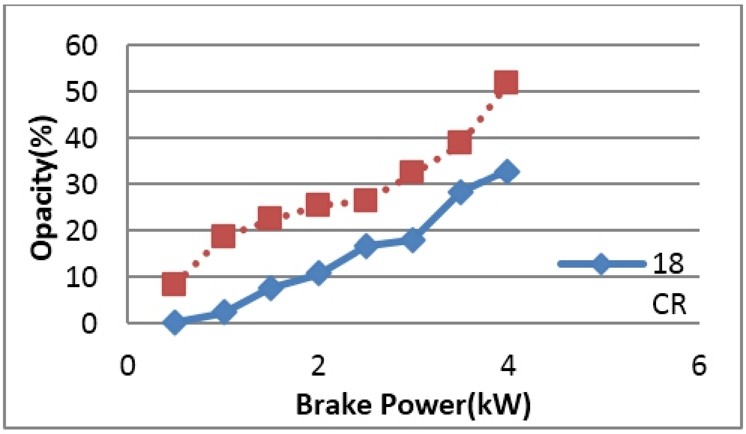


Fig.6 : Comparison of Opacity v/s Brake Power for B-60 at different compression ratios

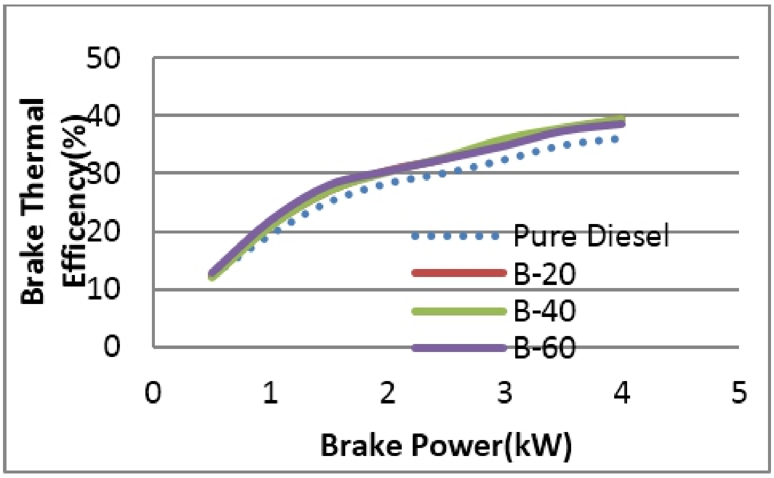


Fig.7: Comparison of BTE v/s Brake Power for diesel and CSOME blends at 18 CR.

4.1 Variation of the smoke opacity w.r.t. brake power at 16 CR

Fig. 2 shows that smoke opacity value for neat diesel is slightly lower as compared to the diesel-CSOME blends. Biodiesel has about 10% oxygen by weight, which results in decrease of smoke opacity. However, its higher viscosity results in increase in smoke opacity. At lower compression ratio (16) effect of volatility dominates the effect of oxygen content. Probably vaporization and atomization of high viscosity fuel become difficult at lower compression ratios.

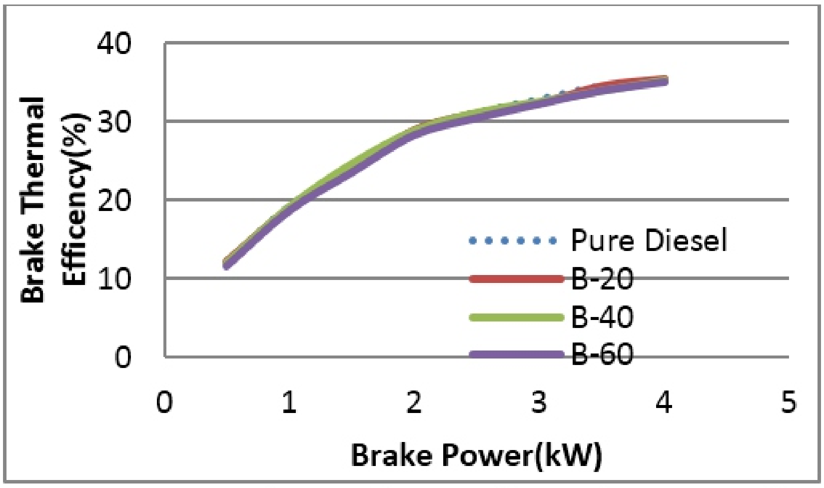


Fig.8: Comparison of BTE v/s Brake Power for neat diesel and CSOME blends of at 16 CR

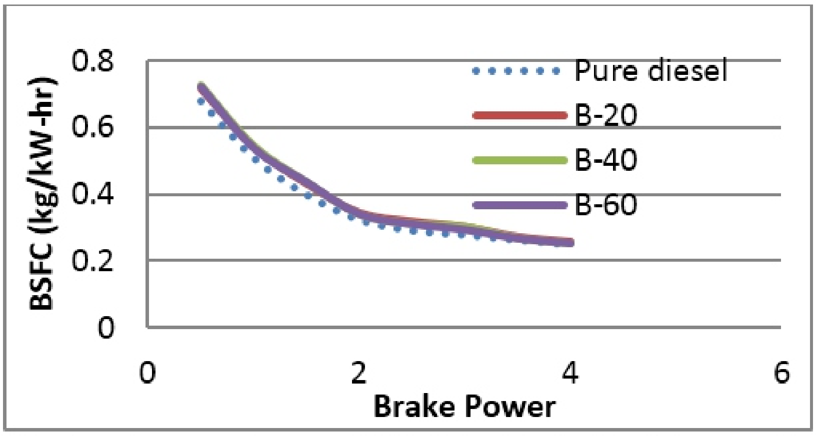


Fig.9: Comparison of BSFC v/s Brake Power for diesel and CSOME blends at 18 CR

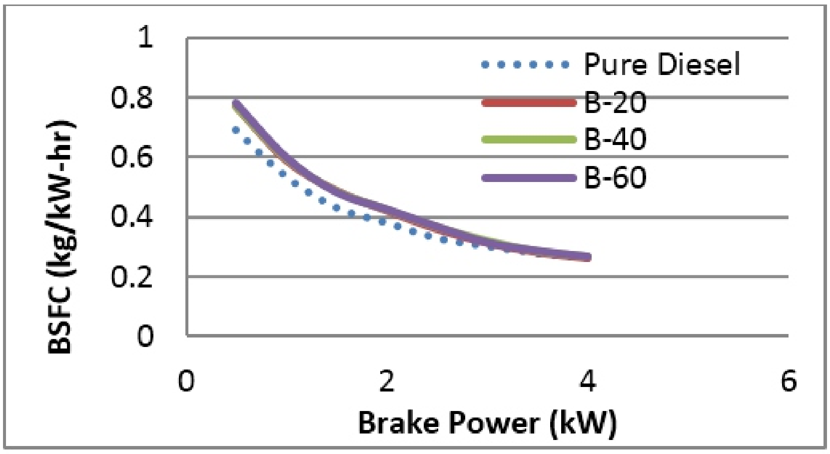


Fig.10: Comparison of BSFC v/s Brake Power for neat diesel and CSOME blends at CR 16

4.2 Variation of smoke opacity w.r.t. brake power at 18 compression ratio

Fig.3 shows opacity value for all diesel-CSOME blends increases from 1% to 33% between the brake power ranges of 0.5 and 4kW brake power. The trend regarding the variation of opacity values w.r.t. brake power is almost similar for all types of blends. The opacity value for neat diesel is slightly higher as compared to all types of blends. Addition of CSOME to neat diesel increases the viscosity and oxygen content of the fuel. The effect of latter dominates at 18 compression ratio and thus decrease in opacity is noticed for all diesel-CSOME blends. Extremely low sulphur in biodiesel also results in low smoke opacity.

4.3 Variation of opacity w.r.t. brake power for B-20, B-40, B-60 blends at different compression ratios

Fig.4 to 6 shows opacity values for B-20, B-40, B-60 blends respectively. It shows that smoke opacity decreases at higher compression ratios as the effects of higher viscosity and lower volatility reduces as compression ratio increases.

4.4 Variation of BTE w.r.t. brake power at 18 compression ratio

Fig. 7 shows the variation of BTE v/s brake power for diesel-CSOME blends in comparison to neat diesel. For all selected diesel-biodiesel blends, BTE increases with brake power output and the trend is almost similar to diesel. This small gain in BTE as compared to diesel is due to the presence of oxygen in biodiesel molecules and its higher lubricity, which results in better combustion and lower frictional losses.

4.5 Variation of BTE w.r.t. brake power at 16 compression ratio

Fig. 8 shows the variation of BTE v/s brake power for diesel-CSOME blends in comparison to neat diesel. For all selected blends BTE increases with brake power output and the trend is almost similar with diesel. No significant change in BTE is seen, when using diesel-CSOME blends as compared to diesel. Diesel-CSOME blends show poor vaporization and atomization characteristics at lower compression ratios due to higher viscosity and lower volatility. This counteracts the effect of increase in BTE due to the presence of oxygen in biodiesel molecules and higher lubricity.

4.6 Variation of BSFC w.r.t. brake power at 18 compression ratio

Fig. 9 shows the variation of BTE v/s brake power for diesel-CSOME blends in comparison to neat diesel at 18 compression ratio. BSFC values were found to be slightly higher than those of neat diesel inspite of increase in BTE with diesel-CSOME blends. This is due to lower heating values of diesel-CSOME blends and thus more fuel was required for maintenance of constant power output. An indicator of the loss of heating value and thus less than expected fuel consumption is due to the oxygen content of the CSOME blends.

4.7 Variation of BSFC w.r.t. brake power at 16 compression ratio

Fig. 10 shows the variation of BTE v/s brake power for diesel- CSOME blends in comparison to neat diesel at 18 compression ratio. The percentage increase in BSFC, with biodiesel blends as compared to diesel at 16 compression ratio is more as compared to the corresponding increase at 18 compression ratio. This is due to negligible rise in BTE with biodiesel blends at 16 compression ratio.

5. Conclusions

In our study, test engine was operated at steady-state without modifications to engine or injection system. Using data gathered from the present study, energy balances to the engine were performed for the either fuel. And then, energetic performance parameters of the engine computed and compared with each other. Since the net calorific value of diesel is greater than that of the biodiesel. It means that to cover the same distance, greater amount of biodiesel is needed. In addition to this, using of biodiesel fuel shows the similar energetic performance values with that of diesel fuel.

In our study, the first and second Laws of thermodynamics are employed to analyze the quantity and quality of energy in a single-cylinder, direct injection diesel engine using petroleum diesel fuel and biodiesel fuel. The experimental data are collected using steady-state tests which enable accurate measurements of air, fuel and cooling water flow rates, engine load, and all the relevant temperatures.

The results of tested biodiesel offer similar energetic performance as petroleum diesel fuel. Special attention is given to identification and quantification of second-law efficiencies and the irreversibilities of various processes and subsystems. The latter being particularly important since they are not identified in traditional first-law analysis.

High biodiesel conversion yield is obtained for combined (hydrodynamic cavitation and mechanical stirring) process as compared to hydrodynamic cavitation or mechanical stirring alone. Higher percentage of catalyst does not have much impact on biodiesel production. Smoke opacity values were lower for diesel-CSOME blends as compared to neat diesel when the engine is operated at 18 compression ratio. Brake Thermal Efficiency for diesel- CSOME blends was higher as compared to neat diesel when the engine is operated at 18 compression ratio. Brake specific fuel consumption for diesel-CSOME blends was higher as compared to neat diesel inspite of increase in Brake Thermal Efficiency.

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Performance Analysis of Solar Air Conditioning: A Review

Ashok Kumar Yadav[1‡], Vikram Pandey[2] , Sachin Singh[2], Suyash Rai[2], and Abhinav Verma[2]

[1]Associate Professor, Department of Mechanical Engineering,

Raj Kumar Goel Institute of Technology, Ghaziabad, 201003, India

Email: ashokme015@gmail.com

[2,]B. Tech students, Department of Mechanical Engineering,

Raj Kumar Goel Institute of Technology, Ghaziabad, 201003, India

Email: vikrampandey310@gmail.com2, coolsachin2737@gmail.com3 , suyashrai600@gmail.com4, abhinavverma1495@gmail.com5

[‡]Corresponding Author; Tel: +91 8285423046

ABSTRACT

This paper represents a review of new solar based air conditioning techniques. These techniques used solar energy to produce cold or hot air and do not pollute the environment. Thermally driven cooling system is the key component of these systems. The use of solar powered air conditioning systems for heating and cooling requirements in the buildings would be more economical. Though various air conditioning systems run on solar power have been tested extensively, there have been very less focus on the use of solar powered air conditioning systems. Aim of this paper is to review the literature on emerging technologies for solar air conditioner and provide knowledge which will be helpful to initiate the study in order to investigate the influence of various parameters on the overall system performance.

Keywords- solar air-conditioning; pcm; adsorption

1. INTRODUCTION

The demand for human comfort is increasing day by day. The International Institute of Refrigeration in Paris has estimated that approximately 15% of all the electricity produced in the whole world is employed for refrigeration and air-conditioning processes of various kinds, and the energy consumption for air-conditioning systems has recently been estimated to be 45% of the whole households and commercial buildings. Most of this demand is being met by vapour compression based refrigeration system. Recently, though nominal, some vapour absorption based refrigeration systems have come for industrial and office building use. Solar energy can be used for air-conditioning in two ways – electricity through solar photo-voltaic cell and then using the same in conventional i.e. vapour compression cycle and the heat driven sorption system. The improvement in solar photo-voltaic cell efficiency is very slow and so initial cost is very high till now. Among the heat driven systems, vapour absorption systems are already commercially available, but mostly having capacity of more than 30 TR. They have limitations for smaller capacity.

2. MAIN COMPONENTS IN SOLAR AIR- CONDITIONING

The main components in the solar assisted air conditioning system can be divided into five main components namely:-

1. Solar collector
2. Hot water & chilled water storage
3. Chiller (cold production)
4. Cooling towers
5. Fan coils

3. SOLAR AIR CONDITIONERS

Grenier et al. [1] built a large cold store of volume 12 m3 powered by solar energy using a zeolite 13-water combination.The evaporator temperature achieved was as low as 2.5 8C, corresponding to a solar COP of 0.086. Comparing these results reveals that the technology does not show any size advantages and, therefore, could be adaptable to large, small and medium size refrigerators. Sakoda and Suzuki [2] constructed and tested a laboratory scale closed adsorption cooling system employing a silica gel–water combination. The successful operation of this unit demonstrated clearly both the experimental and technical feasibility of solid adsorption refrigeration.

4. SOLAR ICE MAKERS

Critoph [3] built a laboratory scale activated carbon–ammonia refrigerator. The evaporator temperature attained was up to _1 8C and about 3 kg of ice was manufactured. The peak collector temperature for the simulated day tests was 115 8C, and the solar COP was 0.04. Although the COP and ice production of this machine are less than those of an activated carbon–methanol pair machine, activated carbon–ammonia system is less sensitive to small leakages, which makes it more reliable for application in remote areas where maintenance is not readily available.

Wang et al. [4] proposed a solar-powered continuous solid adsorption refrigeration and heating hybrid system. A solar water heater and an adsorption icemaker are joined in the same machine.The machine used the working pair activated carbon–methanol and had 2 m2 of evacuated tube collectors to warm 60 kg of water up to 90 8C. The daily ice production was about 10 kg when the insolation was about 22 MJ/m2.

5. THE PROCESS

Rastogi et al. [5] discussed about commercialization of Phase Change Materials (PCMs) for heating, ventilation and air-conditioning (HVAC) applications, has paved way for effective utilization of ambient thermal fluctuations. They attempted to extend Multiple Criteria Decision Making (MCDM) approach for ranking and selecting PCMs for domestic HVAC application. The graded materials were ranked using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). It was observed that the results obtained by simulation are in good agreement with those obtained using MCDM approach. The candidates with the best ranks showed significant improvement in ameliorating the temperature conditions. Thus it can be concluded that integration of MCDM approach for PCMs selection would prove to an economical and swift alternative technique for ranking and screening of materials. Through the proposed work, the authors have attempted to screen and rank various commercial Phase Change Materials for heating, ventilation and air-conditioning application. A Multiple Criteria Decision Making approach was used for this purpose. Suitable materials were first shortlisted based on the phase change temperature (within the range of 17–25 ^{0}C).

Prasartkaew et al [6] Renewable energy based technologies can be introduced for building cooling applications. Most studies on solar absorption cooling use fossil energy based auxiliary heaters. The results demonstrate that the system operates at about 75% of nominal capacity at an average overall system coefficient of performance of about 0.11. Performances of individual components of the system were also evaluated. The experimental results compared with results from other studies shows that the proposed system's performance in terms of chiller and overall system coefficient of performance is superior. The results demonstrate that the system operated at about 75% of nominal capacity and an average overall system coefficient of performance of about 0.11 was achieved. The results also show that, due to the limitation of heat absorption at the evaporator of this (small size) chiller, the supplied excess heat was rejected at the cooling tower. The biomass-gasifier boiler system, used as a booster/auxiliary heater, can improve the overall system performance. Comparison of performance of solar cooling system with different auxiliary heat sources shows that the proposed system outperforms the others, in terms of chiller and overall system coefficient of performance.

Bach et al. [7] used is a solid adsorption system to describe a new solar based air conditioning techniques. Suggested design procedure is simple and does not require a high technology. This type of unit can be used widely in the regions with an abandoned solar resource.

Younes et al.[8] studied Lithium – Bromide absorption machine thoroughly, showing the amount of fuel used in last few years for air conditioning. Also by studying each main part of the machine and different parameter; it was found that the length of the tubes required can be calculated to ensure the transfer of heat. This study showed that the machine needs six years and eight months to retain its costs with an annual payback of $120000.

Xia et al. [9] applied for a patent of a silica gel–water adsorption chiller driven by a low temperature heat source that was used to cool a grain depot in the Jiangsu Province, China. This chiller has two identical chambers and a second stage evaporator with methanol as working fluid. Each chamber contains one adsorber, one condenser and one evaporator (the first stage evaporator).

Li et al. [10]. The estimated thermal COP is about 0.4 under the following operating conditions: condensing temperature 40 8C, evaporating temperature 10 8C, regenerating temperature 120 8C and desorbing temperature 200 8C, using zeolite 13_–water as the working pair.

Yadav et al. [11] discussed about Peltier effect with which one can cool a specific area without using compressor which take a huge consumption of electricity.This system is driven by solar energy using solar plates, battery, transformer peltier module and heat sink. The analysis showed that for the prevalent conditions the compressor less AC is significantly more economical to own and operate than the conventional AC. In spite of a slightly higher initial cost, the thermoelectric AC proves to be more economical, mainly due to its significantly lower operating cost.

Wang [12] compared the COP of adsorptions systems with and without mass recovery and found that the former could produce a COP from 10% to 100% higher than the latter. The differencebetween the COPs was higher at lower generation temperatures.
in brief above work is reported in below table1

Table: 1 Summary of important work

Author	Work study	Result
Rastogi et al.[5]	Phase change material (Pcm's)	MCDM proved to be a suitable technique to choose suitable pcm
Prasartkaew et al. [6]	COP of renewable energy in cooling applications	Superior results in terms of solar chillers
Wang et al. [4]	Solar adsorption and heating hybrid system	daily ice production was about 10 kg when the insolation was about 22 MJ/m^2
Critoph. [3]	Activated carbon ammonia refrigerator	advantages and limitations of the simultaneous transport of heat and adsorbate in a closed type adsorption cooling system.

6. MAJOR ISSUES

The adsorption systems must have their size and cost reduced to become more commercially attractive. The most promising alternatives to achieve these goals include the enhancement of the internal and external heat transfer of the adsorber to increase the SCP, and the improvement of the heat management to increase the COP. The main technologies to enhance the external heat transfer in the adsorber are related to the increase of the heat exchange area, the use of coated adsorbers and the utilization of heat pipe technology. To improve the internal heat transfer, the most suitable option is the employment of consolidated adsorbents.

7. CONCLUSIONS

The principal challenge for adsorption refrigerators powered by solar energy is to overcome several failed attempts to commercialize them. Although investment costs for adsorption chillers using silica gel are still high, the environmental benefits are impressive , when compared to conventional compressor chillers. The absence of harmful or hazardous products such as CFCs, together with a substantial reduction of CO2 emissions due to very low consumption of electricity, creates an environmentally safe technology. Low temperature waste heat or solar energy can be converted into a chilling capacity as low as 5 8C with minor maintenance costs. Finally solar air conditioning has proved to be a good alternative for vapour compression system.

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