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## The Volume 10

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highlights

- Lambda Calculus and Functional Programming
- Dioxane Blended Fuels
- Elemental Sulphur Saturation
- Cylindrical Catalyst

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# *From the Chief Author's Desk*

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Dr. R. K. Dixit
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# Optimization of Injection Parameters For A Stationary Diesel Engine

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P. srikanth[4] M.Suresh[5] Y. Mohan Raviteja[6]

GJRE Classification (FOR) A,B 090201, 091302

***Abstract*- Experiments were carried out on a 4 stroke single cylinder diesel engine at various injection pressures and injection timings to find the optimum values of the same towards obtaining better performance. The selected engine is made to run at rated speed and varying loads. All the readings were taken while maintaining the cooling water exit temperature at its optimum value. The results showed a better performance with the engine at an injection pressure of 200 bar and Injection timing 110 BTDC.**

*Keywords*-Diesel engine, optimum injection timing, optimum injection pressure, performance appraisal.

## I. INTRODUCTION

Due to rapid depletion in the fossil fuel reserves, it is high time now to think about alternatives to the use of petroleum fuels in the diesel engines. Lot of research activities have been taking place in search of suitable alternative to the diesel oil in diesel engines. Before such an alternative is found, it's wise to look for improving the performance of the existing engine by suitable engine modifications. An attempt is made here to study the behavior of an existing diesel engine at various injection pressures and injection timings.

## II. LITERATURE REVIEW

***Srithar Rajoo*** et.al **[12]** has conducted experiment to evaluate the coolant temperature effect on gasoline engine particularly the fuel consumption. Recent researches in automotive field have been concentrated on alternative fuel due to the fact that crude petroleum oil is becoming scarce. Apart from this, it is equally essential to study into currently available engines and improvise it to reduce fuel consumption. In this effort, an engine used in Malaysian made cars was tested under different coolant temperature and its corresponding fuel performance was recorded. In order to manually alter the coolant temperature, an independent cooling tower was built to be attached to the test engine via hose connection. It was found that, when coolant temperature increased from 70°C to 100°C, the fuel consumption of the engine decreases gradually and stabilizes after 90°C.

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***Venkataramana Reddy,*** et.al **[2]** presented some findings of the use of honge oil and diesel fuel blend in direct injection diesel engine with increased injection opening pressure (IOP). The performance, emissions and combustion parameters of 20% honge oil and 80% diesel fuel (volume basis) were found very close to neat diesel fuel where as higher blend ratios were found inferior compared to neat diesel fuel. Improved premixed heat release rate were noticed with H30 when the IOP is enhanced. Performance and emissions with H30 are even better than neat diesel fuel at enhanced IOP. With increased injection pressure amount of honge oil in blend can be increased from 20% to 30%.

***M. Al-Hasan,*** **[5]** conducted experiment on a four-stroke four-cylinder spark ignition engine alternatively equipped with CIS and EIS. Fuel consumption; and exhaust emissions included hydrocarbon, carbon monoxide and carbon dioxide were measured as a function of ambient temperature; i.e. 7, 25 and 40ºC. In order to simulate engine operation condition during warm - up period under various ambient temperatures axillaries cooling water and cooling air systems were designed and coupled to the engine being tested. Results show that as the ambient temperature increases the concentration of both hydrocarbon and carbon monoxide and fuel consumption decreases while the carbon dioxide increases. Also, the time required for the engine to fully warm-up is shortened. Moreover, operating the engine when equipped with EIS has a greater effect on HC, CO and fuel consumption reduction compared to When equipped with CIS at the same operation conditions.

***Rosli Abu Bakar,*** et.al **[9]** investigated effects of fuel injection pressure on engine performance. Experiments have been performed on a diesel engine with four-cylinder, two-stroke, direct injection. Engine performance values such as indicated pressure, indicated horse power, shaft horse power, brake horse power, break mean effective pressure and fuel consumption have been investigated both of variation engine speeds - fixed load and fixed engine speed – variation loads by changing the fuel injection pressure from 180 to 220 bars. According to the results, the best performance of the pressure injection has been obtained at 220 bars, specific fuel consumption has been obtained at 200 bars for fixed load – variation speeds

and at 180 bar for variation loads – fixed speed. The results of the experiment have given as graphics in this pape

.***Cenk Sayin,*** et.al **[1]** investigated ethanol-blended diesel fuel from 0 to 15% with an increment of 5%. The engine has original injection pressure of 200 bar. The tests were conducted at three different injection pressures (180, 200 and 220 bar) with decreasing or increasing washer number. All tests were conducted at four different loads (5, 10, 15, and 20 N m) for constant engine speed of 2200 rpm. The experimental test results proved that brake thermal efficiency, heat release rate, peak cylinder pressure, smoke number, carbon monoxide and unburned hydrocarbon emissions reduced as brake-specific fuel consumption, brake specific energy consumption, combustion efficiency, and nitrogen oxides and carbon dioxide emissions increased with increasing amount of methanol in the fuel blend. When comparing the results to the original injection pressure, at the decreased injection pressure (180 bar), peak cylinder pressure, rate of heat release, combustion efficiency, and nitrogen oxides and carbon dioxide emissions decreased, whereas smoke number, unburned hydrocarbon, and carbon monoxide emissions increased at all test conditions. On the other hand, with the increased injection pressure (220 bar), smoke number, unburned hydrocarbon, and carbon monoxide emissions diminished, and peak cylinder pressure, heat release rate, combustion efficiency, and nitrogen oxides and carbon dioxide emissions boosted at all test conditions. With respect to brake-specific fuel consumption, brake-specific energy consumption, and brake thermal efficiency, changing injection pressure gave negative results in the all fuel blends compared to the original injection pressure.

***Purushothamana K***. et.al **[8]** investigated the effect of injection pressure on the combustion process and exhaust emissions of a direct injection diesel engine fueled with Orange Skin Powder Diesel Solution (OSPDS). In the present investigation the injection pressure was varied with 30% OSPDS and the combustion, performance and emissions characteristics were compared with those of diesel fuel. The different injection pressures studied were 215 bar, 235 bar and 255 bar. The results showed that the cylinder pressure with 30% OSPDS at 235 bar fuel injection pressure, was higher than that of diesel fuel as well as at other injection pressures. Similarly, the ignition delay was longer and with shorter combustion duration with 30% OSPDS at 235 bar injection pressure. The brake thermal efficiency was better at 235 bar than that of other fuel injection pressures with OSPDS and lower than that of diesel fuel. The $NO_x$ emission with 30% OSPDS was higher at 235 bar. The hydrocarbon and CO emissions were lower with 30% OSPDS at 235 bar. The smoke emission with 30% OSPDS was marginally lower at 235 bar and marginally higher at 215 bar than for diesel fuel. The combustion, performance and emission characteristics of the engine operating on the test fuels at 235 bar injection pressure were better than other injection pressures.

***Murari Mohon Roy,*** **[6]** investigated the effect of fuel injection timing and injection pressure on combustion and odorous emissions in a direct injection diesel engine. Injection timings from 15 deg before top dead center (BTDC) to top dead center (TDC) and injection pressures from 20 Map to 120 Map were tested. In emissions, exhaust odor, irritation, aldehydes, total hydrocarbon, and hydrocarbon components are compared in different injection timings and injection pressures condition. Injection timings where main combustion takes place very close to TDC are found to show minimum odorous emissions. Moderate injection pressures (60–80 MPa) showed lower emissions including odor and irritation due to proper mixture formation. Below the injection pressure of 40 MPa, and over 80 MPa, emissions become worse. Combustion analysis is performed by taking cylinder pressures after engine warm-up for different injection timings and injection pressures and analyzing cylinder temperatures and heat release rates. Cylinder pressures and temperatures are gradually decreased when injection timings are retarded. Ignition delay becomes shortest at 5–10 deg BTDC injection timings. The peak cylinder pressure and temperature are increased with higher injection pressures. The shortest ignition delay and minimum emissions is found at around 60 MPa of injection pressure.

***C J Brace,*** et.al **[3]** conducted the experiments on effects of cooling system hardware changes on diesel engine emissions and fuel economy. Experiments were performed under both steady state and transient conditions and complemented by statistical assessments. Techniques for assessing the thermal integrity of the engine as a consequence of such changes are also presented. An experimental design was constructed to investigate the effect of water pump throttling, coolant flow control through the oil cooler, and the adoption of a pressure resistive thermostat (PRT). Use of these thermal controls offers a useful trade-off between $NO_x$ and fuel economy, with a saving of around 3 per cent in b.s.f.c. for a 10 per cent $NO_x$ penalty at low load, where $NO_x$ output is less of a concern. However, these benefits were not observed during drive cycle testing.

***Ns Bari,*** et.al **[10]** examined the changes in the behaviour of waste cooking oil (WCO) with changes in injection timing of a direct injection (DI) diesel engine, compared with those of diesel. The aspects taken into consideration were the effects of injection timing on combustion, performance and emissions. The results reveal that WCO and diesel responded identically to injection timing changes. To reduce $NO_x$ emission, one of the methods is to retard the injection timing from MBT timing. The engine used in this research follows this technique and had its original injection timing set at 15Â° before top dead centre (BTDC). With injection timing advanced by 4Â°, the engine produced better e ciency by 1.6 per cent for WCO and by 1.1 per cent for diesel, reduced CO emission, by averages of 9.9 per cent for WCO and 44.9 per cent for diesel, but su ered increased NO emission of 76.6 per cent for WCO and 91.4 per cent for diesel. In all instances, WCO had shorter ignition delays than diesel, but the ignition delay for WCO was more sensitive to load and injection timing than that for diesel.

The test engine could run on WCO with the original injection timing, and altering the timing could result in a trade-o between performance and emission. ***M. I. Nwafor***, **[7]** examined the advanced injection timing on the performance of natural gas used as primary fuel in dual-fuel combustion has been examined. Satisfactory diesel engine combustion demands self-ignition of the fuel as it is injected near the top dead centre (TDC) into the hot swirling compressed cylinder gas. Longer delays between injection and ignition lead to unacceptable rates of pressure rise (diesel knock) because too much fuel is ready to burn when combustion eventually occurs. Natural gas has been noted to exhibit longer ignition delays and slower burning rates especially at low load levels hence resulting in late combustion in the expansion stroke. Advanced injection timing is expected to compensate for these effects. The engine has standard injection timing of 30Â° before TDC (BTDC). The injection was first advanced by 5.5Â° given injection timing of 35.5Â° BTDC. The engine ran for about 5 minutes at this timing and stopped. The engine failed to start upon subsequent attempts. The injection was then advanced by 3.5Â° (i.e. 33.5Â° BTDC). The engine ran smoothly on this timing but seemed to incur penalty on fuel consumption especially at high load levels.

***M. Pandian*** et.al, **[4]** conducted the experiment on Twin Cylinder CIDI Engine Using Bio-diesel Blend as Fuel. Stringent emission norms and environment degradation due to pollutants from the automotive vehicles lead us to find the suitable alternative for the petro-diesel. Among the alternatives the non-edible vegetable oil seems to be most promising one. The transesterification process has proved as one of the best method to achieve the same. It is evident from the literature that the major problem on utilization of blends of bio-diesel is the increase in NOx emission from diesel engines. To reduce the NOx emission from the diesel engines employing biodiesel blend as fuel, the injection timing of fuel is altered by either addition or removal of shims in the pump. The effect of changing the injection timing on BSEC, Brake Thermal Efficiency, CO, HC and NO emissions are studied at different injection timings such as 18°, 21°, 24°, 27° and 30° CA BTDC. From the experiments it is found that on retarding the injection to 18°CA BTDC from 24° CA BTDC, the original injection timing, the NOx emission reduced to about 35% while advancing to 30°CA BTDC, the NOx increased by 25%. The BSEC, CO, HC have been found to increase by about 3%, 12.65% and 10% respectively on retarding to 18°CA BTDC while decrease by 6.27%, 32%,and 14.44% respectively on advancing the injection to 30° CA BTDC. The brake thermal efficiency is reduced by 3.08% on retarding to 18°CA BTDC whereas it is improved by 5.09% on advancing the injection timing to 30° CA BTDC.

## III. Experimentation

An experimental test rig with necessary instrumentation is selected for test purpose. The engine is mounted on a sturdy mild steel chasis and is coupled with rope brake dynamometer. Fuel consumption is measured with the help of a standard burette and air consumption with orifice fitted to an air box. The rate of coolant flow is measured by a turbine flow meter. The layout of the setup is shown in the Fig.4.1. The technical specifications of the engine were presented in Table4.1.

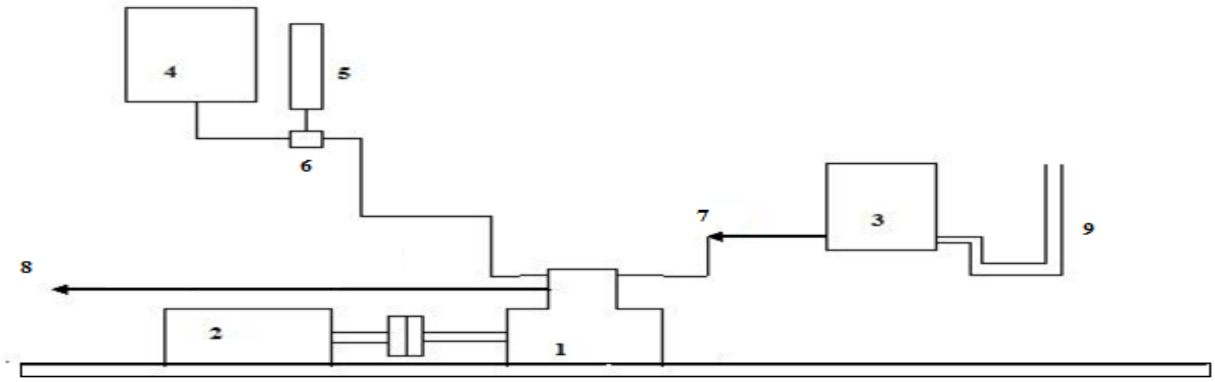


Fig 3.1 Layout of Experimental setup

**1. Engine**
**2. Brake drum dynamometer.**
**3. Air box**
**4. Fuel tank**
**5. Burette**
**6. Three way valve.**
**7. Air flow direction.**
**8. Exhaust flow.**
**9. Manometer**

**Table 3.1: specifications of the engine**

| | |
|---|---|
| Power | 3.7KW |
| Speed | 1500rpm |
| S.F.C | 247gms/kw hr/182gms/bhp |
| Compression Ratio | 20:1 |

## IV. Results and Discussion

### A. *Experimentation at various injection pressures:*

Fig.4.1 shows the variation in BTE with BP at different injection pressures. It can be noted that highest brake thermal efficiency is obtained at an injection pressure of 200bar. The brake thermal efficiencies obtained at full load at an injection pressure of 160bar is 23.43%, at 200bar it is 31.12%, while at 250bar injection pressure, the brake thermal efficiency obtained is 24.45%.

Fig.4.2 shows the variation in mechanical efficiency with Brake power at various injection pressures. It can be observed that the highest mechanical efficiency at full load is obtained with an injection pressure 160bar.

The variation in Exhaust gas temperature with Brake power at different injection pressures is shown in the Fig.4.3. It can be seen that minimum Exhaust gas temperature is obtained at 200bar injection pressure.

From the Fig.4.4 it can be observed that the brake specific fuel consumption is less at 200 bar injection pressure.

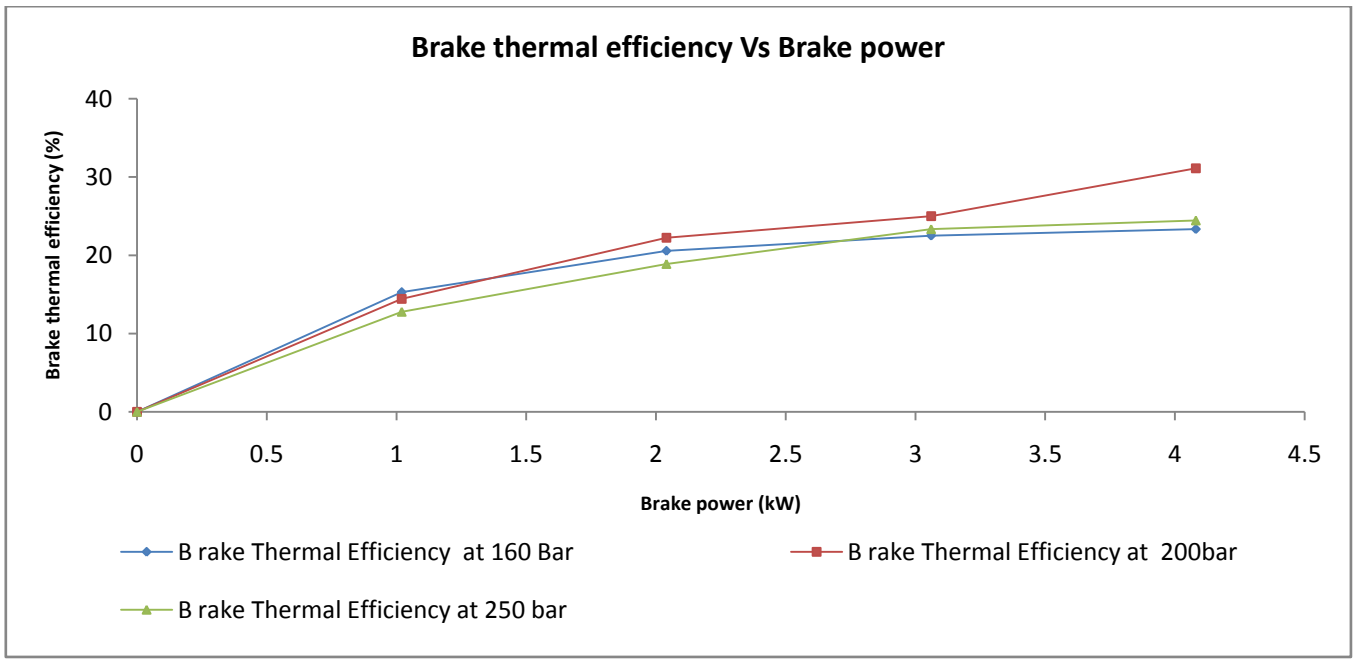


**Fig4.1 Brake thermal efficiency Vs Brake power at different injection pressures**

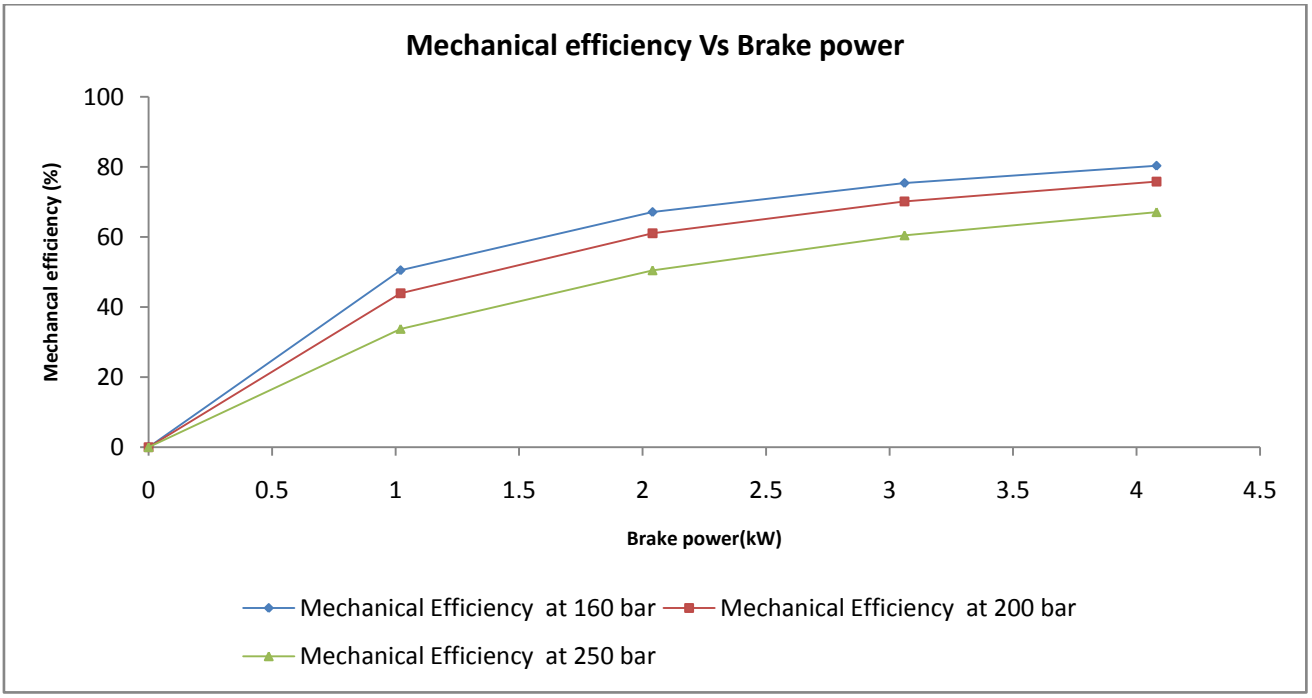


**Fig4.2 Mechanical efficiency Vs Brake power at different injection pressures**

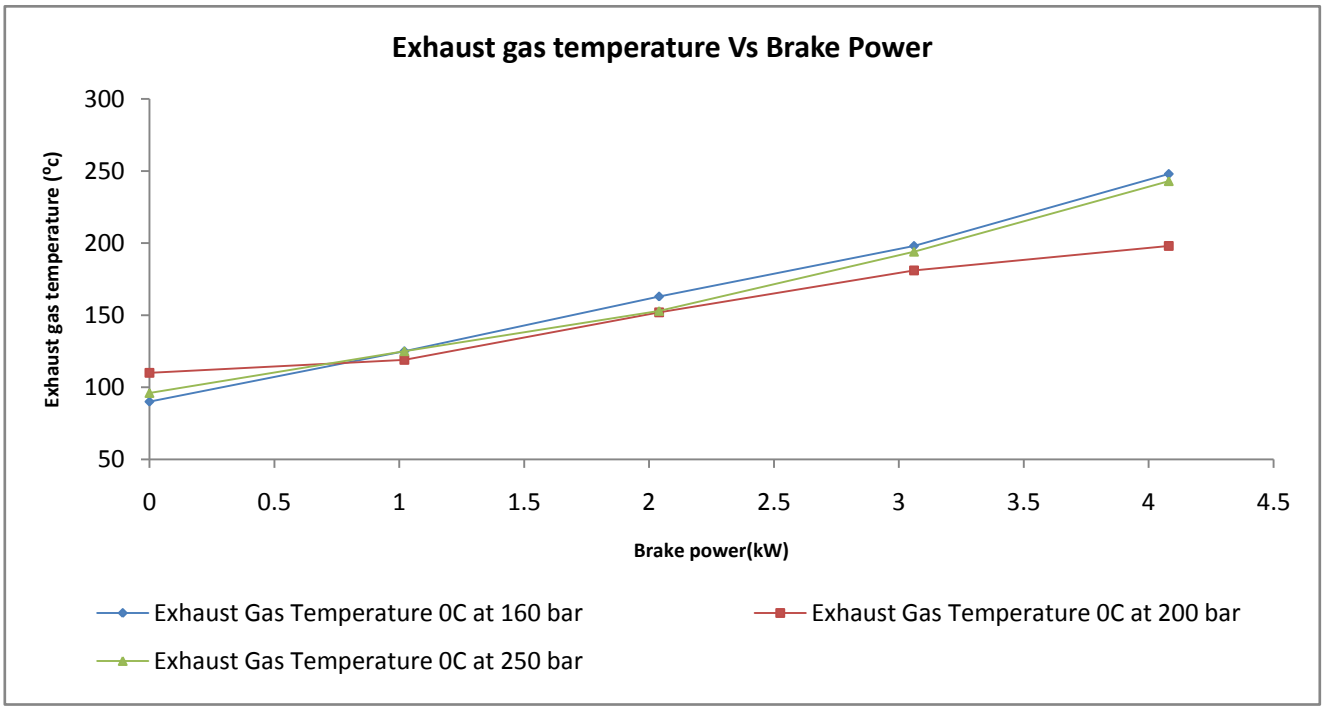


**Fig4.3 Exhaust gas temperature Vs Brake power at different injection pressures**

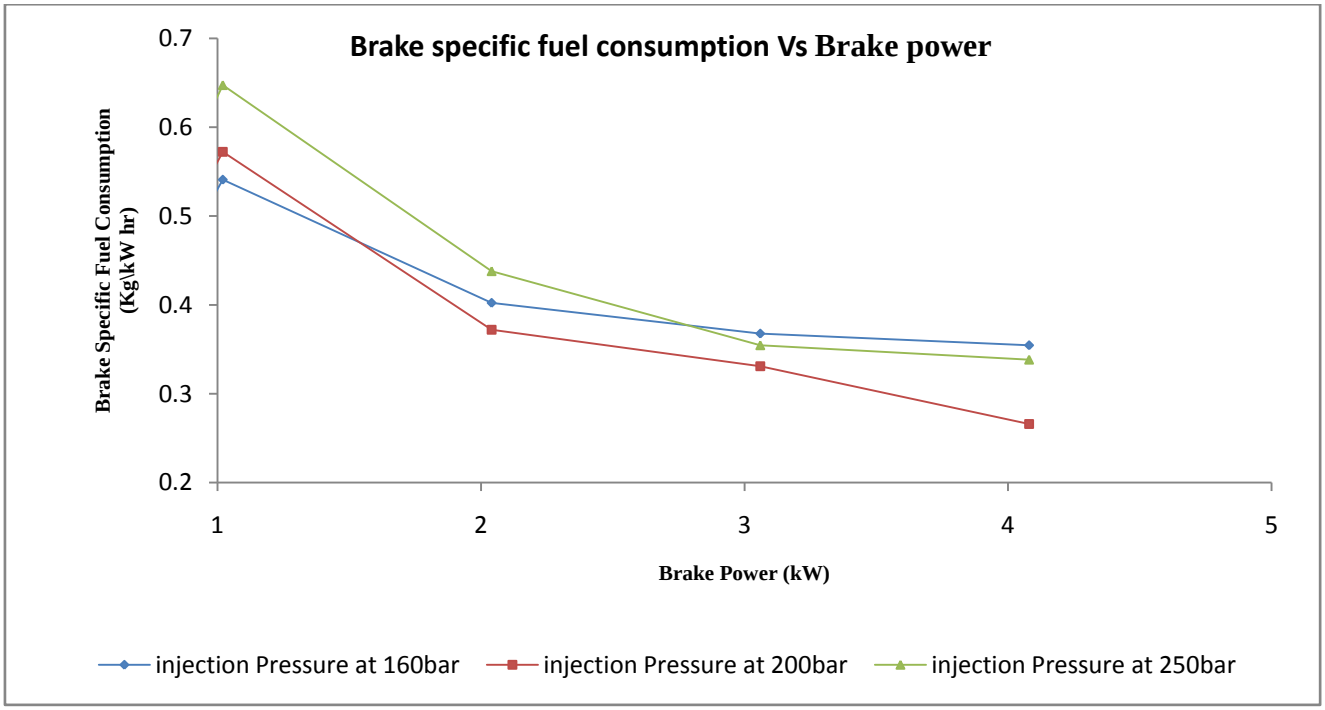


**Fig4.4 Brake specific fuel consumption Vs Brake power at different injection pressures**

*B. Experimentation at various injection timings*

Experiments were carried out on the engine test rig at various injection timings namely 11oBTDC and 140BTDC. The results were shown in the Fig 5.5, 5.6,5.7 and 5.8. From the figures it can be observed that 11o BTDC is the injection timing at which we obtain better Brake thermal efficiency, low Brake specific fuel consumption and Low exhaust gas temperatures.

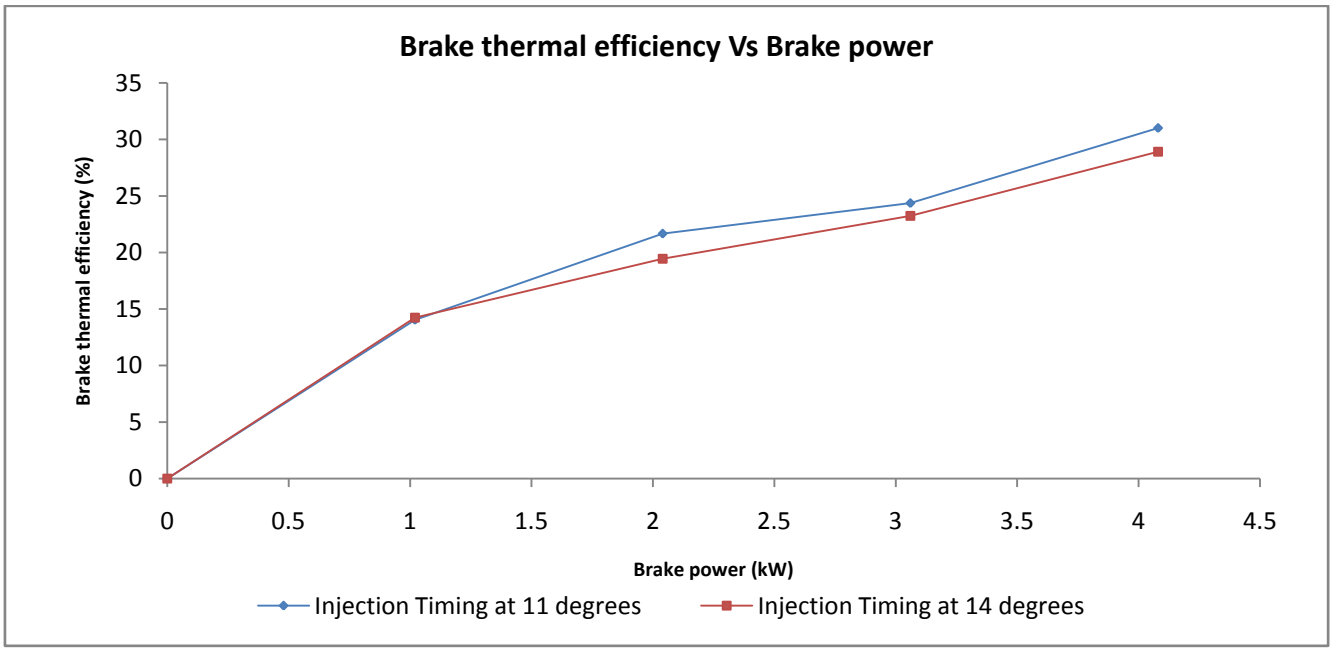


**Fig4.5 Brake thermal efficiency Vs Brake power at different injection timings**

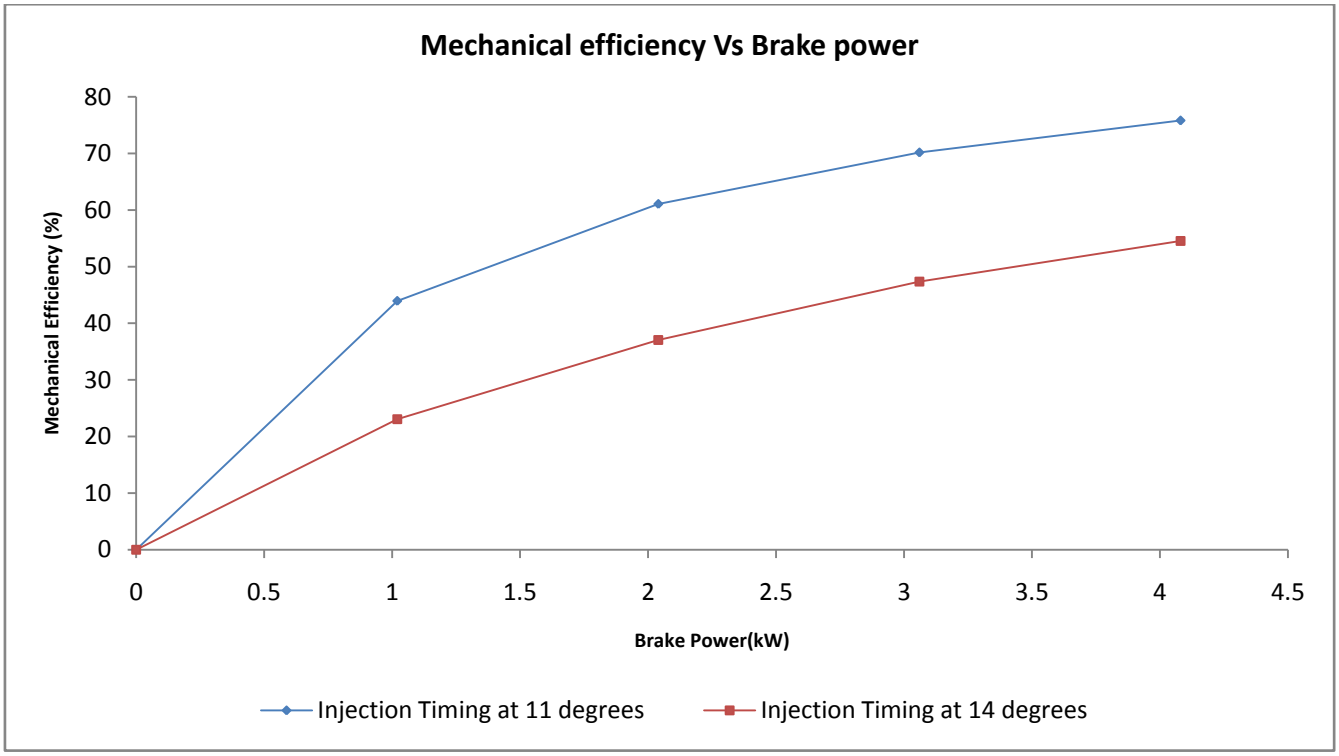


**Fig 4.6 Mechanical efficiency Vs Brake power at different injection timings.**

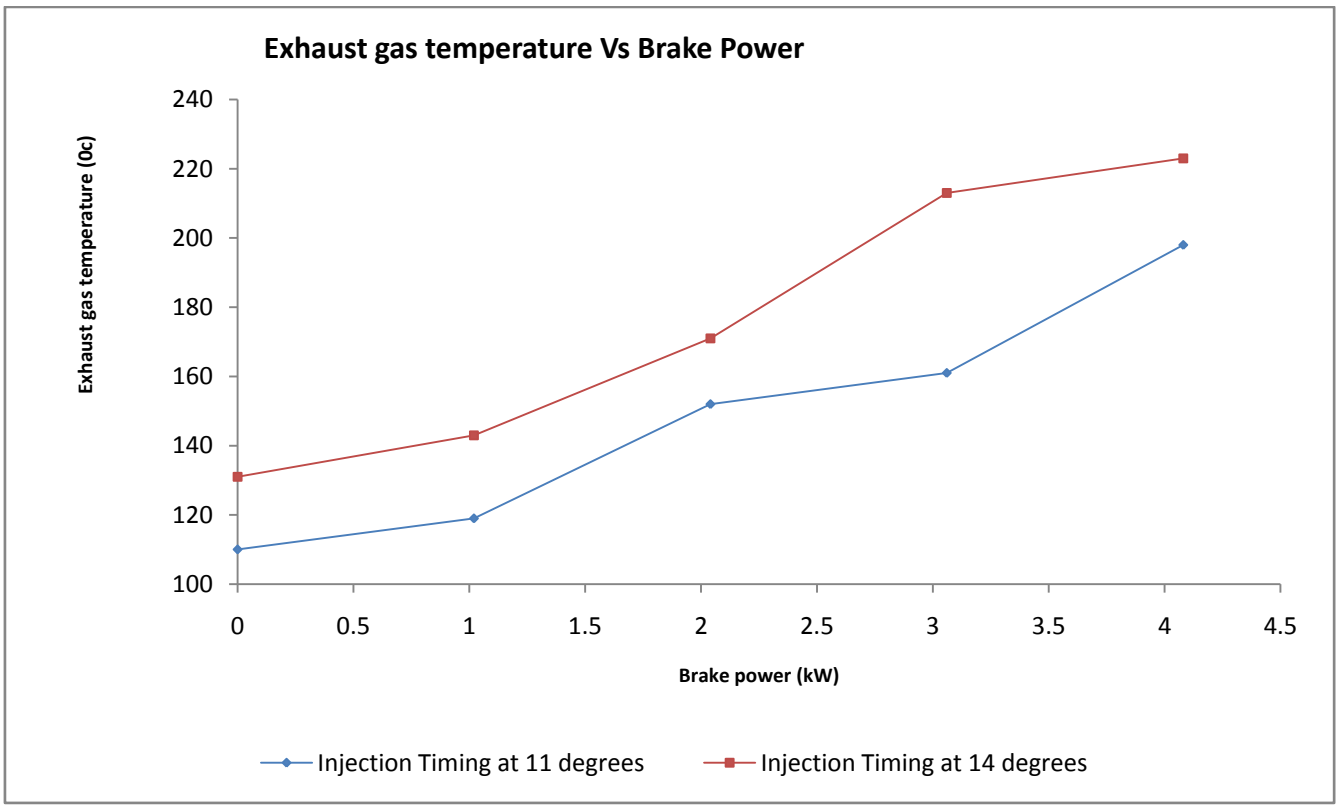


**Fig 4.7 Exhaust gas temperature Vs Brake power at different injection timings.**

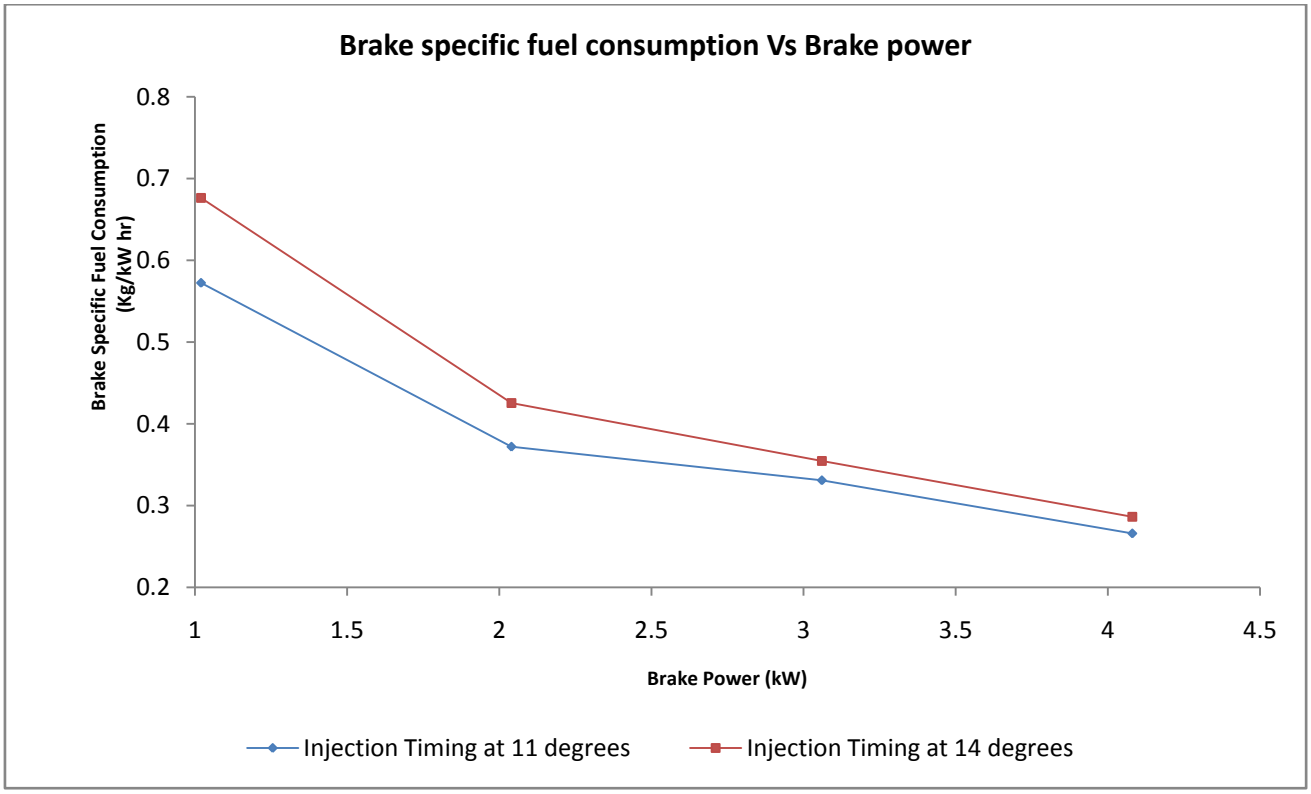


**Fig 4.8 Brake specific fuel consumption Vs Brake power at different injection timings.**

## V. Conclusions

From the experiments carried out on the engine at various injection pressures and injection timings, Following conclusions can be drawn.

At an injection pressure of 200bar and injection timing $11^0$BTDC, the brake thermal efficiency is better

The specific fuel consumption is found to be less at 200 bar injection pressure and injection timing $11^0$BTDC. However there is a slight increase in frictional power at 200bar pressure.

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# Performance of a Thermally Insulated Constant Speed Diesel Engine with Dioxane Blended Fuels

C. Sundar Raj[1] S. Sendilvelan[2] S. Arul[3]

GJRE Classification (FOR)
A,B 090201, 091302, 091305

***Abstract-*** **Dioxane (1,4 Dioxane) An Ether Derived From Alcohol Has Favorable Properties As An Alternative Or Blend Stock For Diesel Fuels. This Work Presents The Comparative Analysis Of Performance, Emission And Combustion Characteristics Of A Single Cylinder Direct Injection Diesel Engine Fuelled With Various Mixtures Of Dioxane And Conventional Diesel Fuel With And Without Thermal Barrier Coating. Results Show Addition Of Dioxane With Diesel Has The Potential To Reduce Smoke Density With Slight Increase In Nox And Drop In Fuel Economy For A Normal Engine While, Increase In Efficiency, Increase In Cylinder Pressure, Reduction In Nox And Reduction In Maximum Heat Release Rate Were Observed When The Engine Components Were Replaced With Zirconia-Alumina Plasma Spray Coated Components.**

## I. Introduction

Due to the shortage of petroleum product and its increasing cost, efforts are on to develop alternative fuels especially to diesel oil for full or partial replacement. The most promising substitutes for petroleum fuels are the alcohols but are not suitable for compression ignition (CI) engines because of its low cetane number and non miscibility. The addition of oxygen containing compounds to diesel fuel has been proposed as a method to complete the oxidation of carbonaceous particulate matter and associated hydrocarbons. In addition, many oxygenates have high cetane number and their association with diesel results in high cetane number and hence lower exhaust emissions. Due to this advantages, there is growing interest in the introduction of oxygenates into diesel fuel.

Di methyl ether (DME) was considered as an ignition-improving additive to methanol powered diesel engines [1]. However, DME is a gaseous fuel and therefore requires that a vehicle be adopted for gaseous operation [2]. In addition, the fuel delivery infrastructure is not currently suitable to distribute large quantities of a gaseous fuel. For these reasons, there is interest in new liquid compression ignition fuels or fuel additives, which have high cetane rating and reduce particulate emissions and at the same time they are compatible with current vehicle technology and fuel delivery infrastructure. Some oxygenated compounds like ethers or methyl carbonates have been tested as additives to improve the performance of diesel fuels [3]. Particularly 1,2-diemthoxyethane, 1,2- dimethoxypropane, butyl ether, 2-methoxyethyl ether, 2- ethoxyethyl ether, pentyl ether and dibutoxymethane [4,5].

Bailey et al. [6] suggest DEE as a potential replacement fuel for CI Engines. The molecular weights of DEE are low; the molecules have high hydrogen to carbon ratios and a low number of carbon-to-carbon bonds. All these properties lower the tendency of forming solid carbon particulate during combustion. The molecules contain oxygen, which also suppress the formation of soot. The molecular bonds break up to radicals at reasonable activation energy, which leads to high cetane numbers.

P. Mohanan et al.,[7] studied the effect of DEE on the performance and emissions of a four-stroke direct injection diesel engine and found that 5% DEE can be blended with diesel fuel to improve the performance and to reduce emissions of the diesel engine even though experiments were carried out successfully up to 25% DEE blend. Gong Yanfeng et al.,[8] proved 15% of 2-methoxyethyl acetate (MEA) can be used to decrease exhaust smoke as a new oxygenated additive of diesel with marginal increase in efficiency.

Zhenkun Lin et al., [9] studied combustion intermediates of a cyclic oxygenated hydrocarbon, 1,4-dioxane at low pressure with an equivalence ratio of 1.80 and found no aromatic intermediates, that was a prominent difference between the fuel-rich flames of 1,4-dioxane and previously studied non cyclic oxygenated hydrocarbons.

C. Sundar Raj et al [10] formed a stable ethanol-diesel blended fuel with the help of 1, 4 dioxane additive, and analyzed the performance, emissions and combustion data for an evaluation of different oxygen content based on ethanol content on a single cylinder DI diesel engine and concluded that 10% addition of 1,4 dioxane by virtue of its properties is capable to stabilize 30% ethanol addition with 60% diesel by volume, and can be used as a blended fuel with diesel in a compression ignition engine with significant reduction in exhaust emissions as compared to neat diesel without any engine modifications.

Approximately one third of the heat released by the combustion of the fuel in a diesel engine is dissipated to the cooling medium. If this can be reduced by thermally insulating the piston crown, cylinder head then the gases in the cylinder will lose less heat and hence, there will be a possibility for extracting more work. The state of art of Thermal barrier coating (TBC) provides the potential for higher thermal efficiencies of the engine. The objective is not only to reduce cylinder heat rejection and thermal fatigue protection of underlying metallic surfaces, but also

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for possible reduction of engine emission. Ceramics have unique thermal, mechanical, chemical and electrical properties, but their high fabrication cost, brittleness and size and shape limitations as monolithic components restrict many potential applications. Plasma spray is one of the methods that offer a flexible and relatively economic means for producing coated engine components.

Banapurmath, N R and Tewari, P G[11] made an attempt to utilize the low volatile Honge oil and Honge oil methyl ester (HOME) in a CI engine to study the performance, combustion, and emission characteristics with a ceramic coating of partially stabilized Zirconium (PSZ) on combustion chamber elements and found improvement in brake thermal efficiency and reduction in emissions. M. B. Beardsley et al [12] demonstrated thermal efficiencies of 54% by single cylinder engine testing on coated engines. Prasad. R et al [13] used PSZ coating on the piston crown face and reported a 19% reduction in heat loss through the piston. P.Ramu and C. G Saravanan [14] studied the effect of $ZrO_2$-$Al_2O_3$ and SiC coating on diesel engines and observed less NOx emission for coated engines. They also found that addition of small quantity of 2-methoxyethyl (MEA) has the potential of reduce NOx, cylinder pressure and heat release rate. C. Sundar Raj et al [15] reported 7% increase in efficiency with considerable amount of smoke reduction for 20% ethanol–diesel with 10% dioxane on $ZrO_2$-$Al_2O_3$ coated engine.

Based on the previous studies the objective of this paper is to study the combustion and emission characteristics of a diesel engine driven by dioxane and diesel blends with TBC (WC) and without TBC (WOC) and to compare the results with sole fuel

## II. Fuel properties

1, 4 dioxane a new oxygenate is investigated in this study. The hydrocarbon moieties of these molecules constitute the hydrophobic portion of the structure due to their strong affinity over diesel fuel while the two oxygen atoms form very strong hydrogen bond with ethanol as shown in Figure 1, therefore it is non ionic and can form a stable, homogenous emulsion with ethanol also.

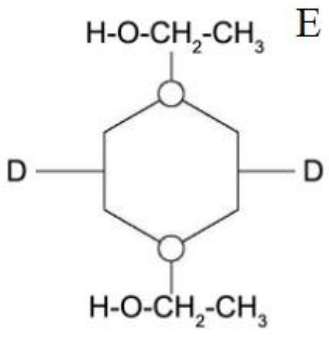


Figure 1 representation of a micelle between the Dioxane, diesel (D) and Ethanol (E)

General fuel properties of 1, 4 dioxane, diesel and the tested values of 50% dioxane and 50% diesel blend (Dy50) are presented in Table 1. It can be seen that, as a compression ignition fuel, dioxane has several favorable properties for on board storage.

**Table 1Chemical properties of Diesel, 1, 4 Dioxane**

| | Molecular Formula | Molecular weight | Density at 20 °C (×103kg/m2) | Boiling point (°C) | Flash point (°C) | Viscosity (mPa s) | Cetane Number | Calorific Value (KJ/Kg) | % of oxygen by weight |
|---|---|---|---|---|---|---|---|---|---|
| Diesel[a] | CxHy | 190–220 | 0.829 | 180 – 360 | 65 – 88 | 3.35 | 45 – 50 | 42500 | 0 |
| Dioxane[b] | $C_4H_8O_2$ | 88 | 1.034 | 101 | 12 | 1.20 | 50 | - | 36 |

[a] Table on Gasoline and Gasohol from Alcohols and Ethers, API Publication 4261, Second Edition (July1988)

[b] United States Environmental Protection Agency, Retrieved on 2006-02-02

## III. Preparation of coating

Commercially available $ZrO_2$ and $Al_2O_3$ ceramic headstock powders (Sulzer Metco) with particle sizes ranging from 38.5 to 63 µm and Ni-20Cr-6Al-Y metal powder (Sulzer Metco NiCrAlY-9) with particle size ranging from 10 to 100 µm were used. The surfaces were grit blasted using 400 mesh $Al_2O_3$ powder. The substrates were grit blasted until a surface roughness of alumina (Ra-4) was achieved. The grit blasted substrates were ultrasonically cleaned using anhydrous ethylene alcohol and dried in cold air prior to coating deposition. A NiCrAlY bond coat of about 150 µm was air plasma sprayed on to the substrate. $ZrO_2$ of 150 µm was deposited over the bond coat and $Al_2O_3$ was sprayed over $ZrO_2$ coat. The thickness of $Al_2O_3$ was also150 µm. Air plasma spray system (Ion Arc 40 KW) was used to deposit the coating. No air cooling on the back side of the substrates was applied during the spraying process.

## IV. Experimental setup and procedure

Experiments were conducted on a, single-cylinder, air-cooled, direct injection diesel engine developing a power output of 5.2 kW at 1500 rev/min connected with a water

Cooled eddy current dynamometer. The engine was operated at a constant speed of 1500 rpm and standard injection pressure of 220 bar. The specification of the engine is given in table 1. The fuel flow rate was measured on volume basis using a burette and a stop watch. K-type thermocouple and a digital display were employed to note the exhaust gas temperature.

**Table 1 Engine specification**

| | |
|---|---|
| Type | Vertical, Water Cooled, Four Stroke |
| Number of Cylinder | One |
| Bore | 87.5 mm |
| Stroke | 110 mm |
| Compression Ratio | 17.5:1 |
| Maximum Power | 5.2 Kw |
| Speed | 1500 Rev/min |
| Dynamometer | Eddy Current |
| Injection Timing | 23° Before TDC |
| Injection Pressure | 220 Kgf/cm2 , Direct Injection |

Smoke level was measured using a standard AVL437C smoke meter. The gas to be measured is fed into a chamber with non reflective inner surfaces. Light produced by an incandescent bulb scatter on the photo cell from reflections or diffused light inside the chamber. The system converts the current delivered from the photocell in to a linear function of the received light within the operating temperature range. The absorption coefficient is calculated in accordance with ECE-R24 ISO 3173 with an accuracy of 0.025 m-1. The equipment has a microprocessor controlled program sequence to check the measurement process and to store such values as pressure, temperature, opacity, absorption.

Exhaust emissions of unburned hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO2), oxygen(O2), oxides of nitrogen(NOx) were measured on the dry basis. A Non Dispersive Infrared (NDIR- AVL-444 digas) analyzer was used. The exhaust sample to be evaluated was passed through a cold trap (moisture separator) and filter element to prevent water vapour and particulates from entering into the analyzer. The analyzer was periodically calibrated according to the instructions of the manufacturer. Hydrocarbons and NOx were measured in parts per million (ppm) hexane equivalents and carbon monoxide, carbon dioxide and oxygen emissions were measured in terms of percentage volume. The accuracy and the measuring range of the analyzer is given in table 2

**Table 2 Accuracy and measuring range of AVL-444 digas analyzer**

| Measured Quality | Measuring Range | Resolution | Accuracy |
|---|---|---|---|
| CO | 0~10 vol% | 0.01 vol% | < 0.6 vol % $\pm 0.03\ vol$ |
| $CO_2$ | 0~20 vol% | 0.1 vol% | < 10 vol % $\pm 0.5\ vol$ |
| HC | 0~20000 ppm vol | ≤ 2000:1 ppm Vol | < 200 ppm vol % $\pm 10\ ppm\ vol$ |
| $O_2$ | 0~22 vol% | 0.01 vol% | < 2 vol % $\pm 0.1\ vol$ |
| NOx | 0~5000 ppm vol | 1 ppm Vol | < 500 ppm vol % $\pm 50\ ppm\ vol$ |
| Engine Speed | 400~6000 $min^{-1}$ | 1 $min^{-1}$ | ±1% of ind. value |
| Oil temperature | -30~125$^0$C | 1$^0$C | ±4$^0$C |
| Lambda | 0~9.999 | 0.001 | Calculation of CO, $CO_2$, HC, $O_2$ |

AVL Combustion analyzer with 619 Indi meter Hardware and Indwin software version 2.2 is used to measure in cylinder pressure, heat release rate, IMEP etc., It consists of inbuilt analog to digital convertor, charge amplifier with PC interface. In cylinder was measured with a water-cooled piezoelectric transducer. The transducer was mounted flush on the cylinder head surface for avoiding passage effects. A piezoelectric transducer produces a charge output, which is proportional to the in cylinder pressure. The charge output was supplied to the inbuilt charge amplifier of the AVL combustion analyzer where it was amplified for an equivalent voltage. A 12-bit analog to digital converter(A/D Converter) was used to convert analog signals to digital form. The A-D converter had external and internal trigging facility with sixteen single ended channels. Data from 100 consecutive cycles can be recorded. Recorded signals were processed with specially developed software to obtain combustion parameters like peak pressure, maximum rate of pressure rise, heat release rate etc. The schematic experimental setup is shown in Figure 2

Base data was generated with standard diesel fuel. Subsequently five fuel blends of dioxane with diesel ranging from 10 to 50% by volume, namely (Dy10, Dy20, Dy30, Dy40 and Dy50) were prepared and tested. Readings were

taken, when the engine was operated at a constant speed of 1500 rpm for all loads. Parameter like engine speed, fuel flow and the emission characteristic like NOx and smoke were recorded. The performance of the engine was evaluated in terms of brake thermal efficiency, brake power, brake specific fuel consumption from the above parameters. The combustion characteristics like cylinder pressure and heat release rate were noted for different blends. The experiments were repeated for the same fuels after thermally insulated the engine with a thin layer ZrO2 – Al2O3 coated piston, cylinder liner, head and bottom of the valves and the results were compared

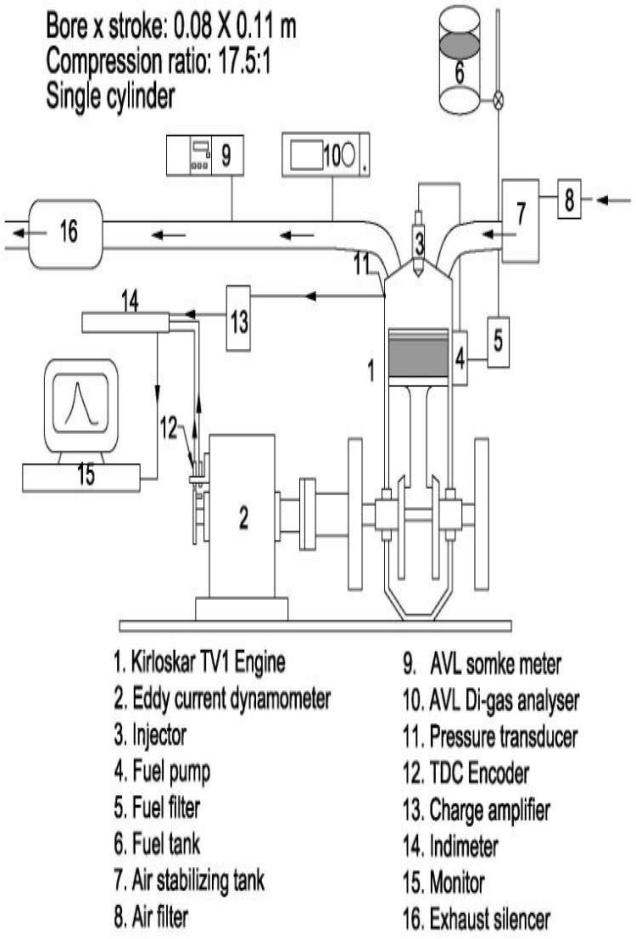


**Figure 2. Experimental setup**

## V. Results and Discussion

As dioxane is having oxygen in its structure, more amount of fuel can be burnt in a given amount of air and hence the BSFC decreases for the blends compared with baseline fuel up to 10% dioxane addition. But, the heat value of the fuel mixture for higher blends decreases as the heat value of dioxane is less than diesel. Hence in order to maintain the same power, more fuels are consumed. As a result, BSFC will increase as the blended fuels with high dioxane concentration are used. Fig.3 shows the BSFC for different dioxane additions with and without thermal insulation. Decrease in BSFC is observed on TBC engines due to substantial reduction in combustion chamber heat transfer and reduced friction due to increased wall temperature as indicated by R. H. Thring [16].

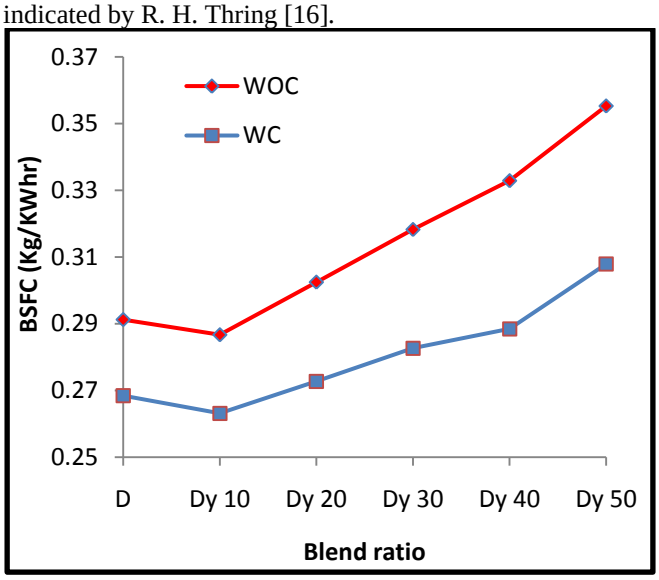


**Figure 3. Brake specific fuel consumption for different dioxane blends at full load**

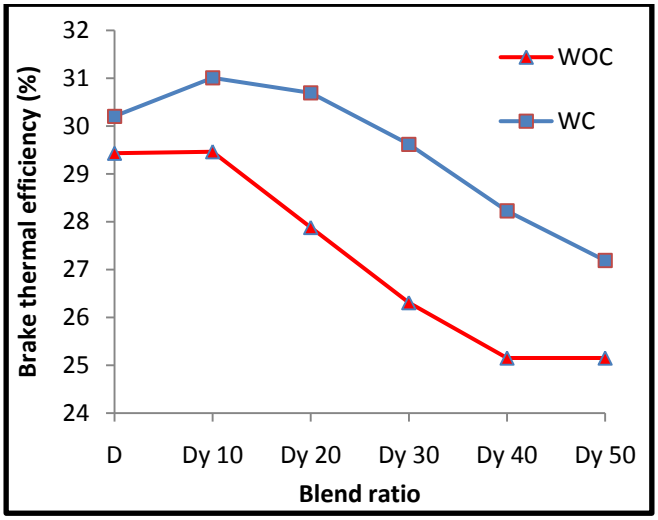


**Figure 4. Brake thermal efficiency for different dioxane blends at full load**

TBC engine improved the brake thermal efficiency of sole fuel by 3.8% when compared to the standard engine due to the in cylinder heat transfer reduction and increase in combustion duration as indicated by Ramu and Saravanan [14].The presence of oxygen due to dioxane in the oxygenated fuel, improve the combustion, especially diffusion combustion and hence increase the brake thermal efficiency. Figure 4 compares the effect of oxygenated fuel blend on the brake thermal efficiency for the standard and TBC engine. The maximum Brake thermal efficiency occurs for B10 blend ratio on the standard engine. The brake thermal efficiency decreases with increase in dioxane

quantity as it reduces total heat value of the mixture. TBC engine recoded higher efficiency than the sole fuel at normal onditions of the engine up to B30 blends and thereafter decreases, hence B30 is considered as optimum blend for a TBC engine.

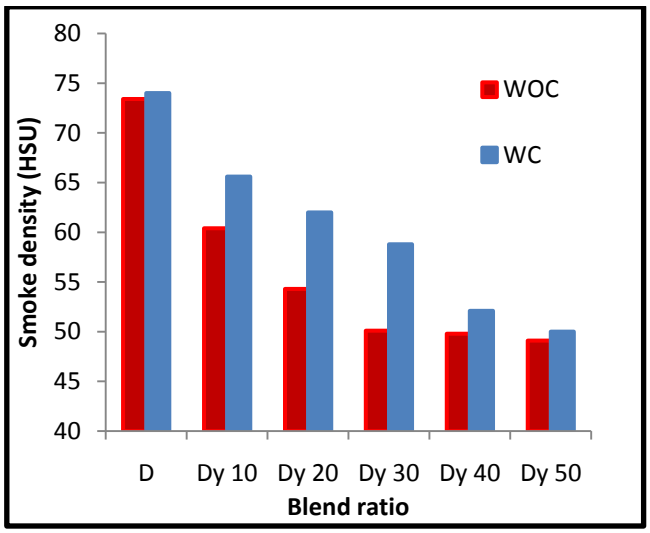


**Figure 5. Smoke density for different dioxane blends at full load**

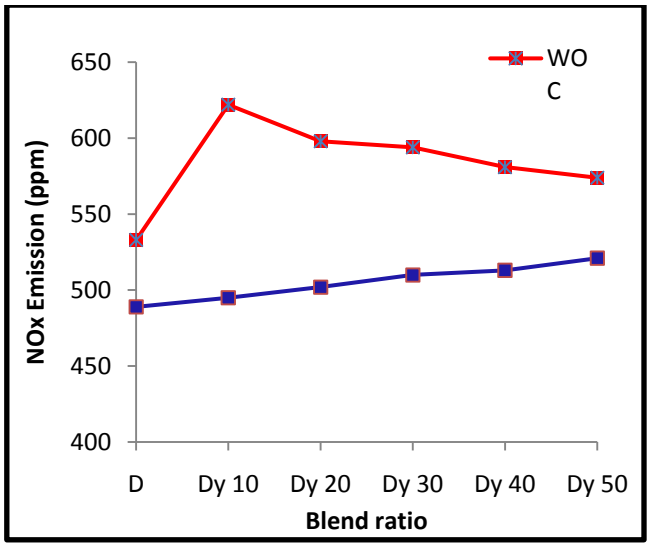


**Figure 6 NOx emission for different dioxane blends at full load**

The variation of smoke density for different dioxane blends at peak load is shown in figure 5. The addition of dioxane, decrease the smoke density. The improvement of smoke emission can be explained by the enrichment of oxygen owing to dioxane. Since the smoke is mainly produced in the diffusive combustion phase, the addition of oxygenated fuel leads to an improvement in diffusive combustion. The results reveal that the tendency to generate soot from the fuel-rich regions inside diesel diffusion flame is decreased by dioxane in the blends. The increase in smoke density for TBC engine may be due to the increase in combustion duration as shown in figure 10.

Fig.6 shows the emission of NOx for different dioxane blends at full load for the standard and TBC engine. Nitrogen oxides emissions are predominately temperature phenomena. In principle, the maximum temperature, residence time, and oxygen concentration in the mixture have a dominant effect on NOx emission. 20% increase in NOx emissions were observed for Dy10 blends. Higher blends show suppressed NOx emission due to retarded ignition timing with an increase in mixing fraction of dioxane. It was predicted that NOx emission increases, because flame temperature of the mixed fuel becomes higher due to advanced homogeneity for a TBC engine. But TBC significantly reduced NOx emissions as the maximum heat release rate occurs in the expansion stroke due to the mixing effect of low flash components.

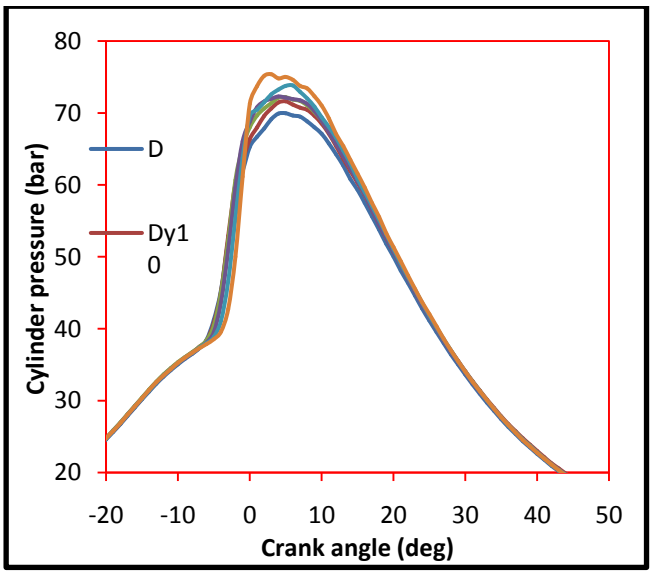


**Figure 7 Cylinder pressure against crank angle**

Dioxane contain oxygen molecule that increase the spray optimization and evaporation. Hence it improves the combustion process of the engine. Fig. 7 illustrates cylinder pressure traces of dioxane blended diesel fuels. It is found that at the same engine speed and maximum load, the ignition delay for the oxygenated blend is higher (the pressure rise due to combustion starts later) than the corresponding one for the neat diesel fuel case, while there is a slight increase in the maximum pressure. C.D. Rakopoulos et al. (2007)[17] obtained the same result for 15% ethanol but with no appreciable difference in the maximum pressure due to the lower cetane number of ethanol. In this case, the increase in pressure is due to the presence of the dioxane which improves the cetane number of the mixture. One can observe from figure 8 that TBC decreases the ignition delay for the oxygenated fuel due to the increasing gas temperature and hence increases the

cylinder pressure. It can also be seen that for the oxygenated fuel on TBC engine higher pressure region change sharply as with diesel engine, but the durations of the higher pressure period is shorter than that of diesel engine.

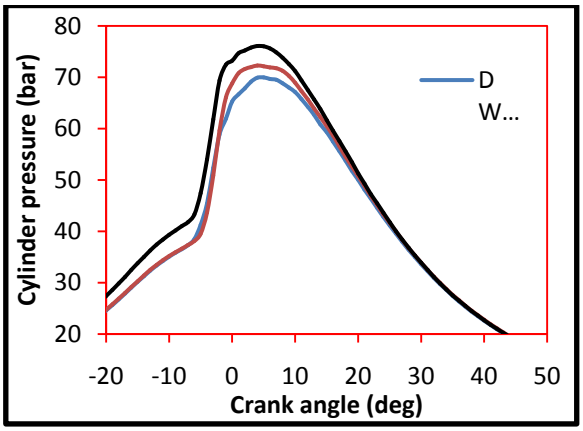


**Figure 8 Comparison of Cylinder pressure against crank angle for Dy30 blends**

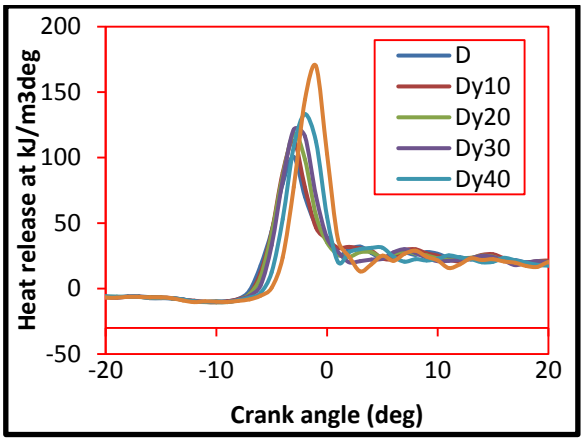


**Figure 9. Heat release rate against crank angle**

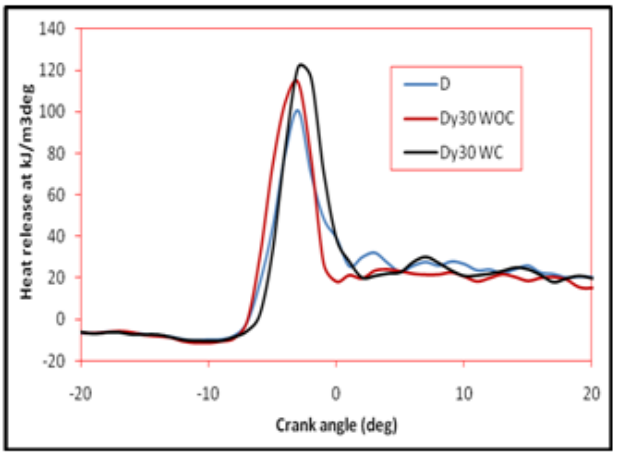


**Figure 10 Comparision of heat release rate for Dy30 blends for the engine WC and WOC**

One can again observe, from the figure 9, that the ignition delay for the oxygenated blend is higher than the corresponding one for the neat diesel fuel case, while its premixed combustion peak is much higher and sharper. It is the lower flash point of dioxane that causes the increase of ignition delay and so the increased amount of 'prepared' fuel for combustion after the start of ignition and is reflected in cylinder pressure. But C.D. Rakopoulos et al. (2007) [17] not experienced any increase in cylinder pressure for 15% ethanol (without any cetane improver) probably because of the counteracting effect of later combustion in a lower temperature environment. It can be seen that for the engine without thermal insulation heat release rate curves of the oxygenated fuel blends and sole fuel shows similar curve pattern although the rate of heat release for the Day 50 shows higher heat release than sole fuel. The reason is the rate of diffusion combustion of the oxygenated fuel increasing the heat release rate – consequently oxygenated fuel has controlled rate of pre-mixed combustion. The heat release rate is further increased for TBC engines due to increased pre-mixed combustion as shown in figure 10.

## VI. Conclusion

The results of the present study may be summarized as follows The Brake specific fuel consumption increase with increase in dioxane, TBC decreases BSFC due to decrease in ignition delay.

Dy10 performs almost equivalent to sole fuel. Whereas, 2.5% improvement of brake thermal efficiency was observed for Dy10 blend when compared to sole fuel for TBC engines Smoke reduction is 19% Dy10 at peak load for the normal engine. Slight increase in smoke is observed for the coated engines.

All blends shows increase in NOx emission when compared to sole fuel at all engine conditions. TBC decreases the NOx emissions The peak pressure and heat release rate for blends are higher than sole fuel and is maximum for coated engines On the whole it is concluded that Dy10 blends can be used as fuel in a compression ignition engine with improved performance and significant reduction in exhaust emissions except NOx as compared to neat diesel and that can be controlled by other techniques like turbo charging, Exhaust gas recirculation etc. The dioxane ratio can further be improved in thermally insulated conditions.

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## VIII. ABBREVIATIONS

| | |
|---|---|
| BSFC | - Brake Specific Fuel Consumption |
| DEE | - Diethyl Ether |
| D | - Diesel |
| Dy | - 1, 4 Dioxane |
| DME | - Dimethyl Ether |
| HSU | - Hatridge Smoke Unit |
| TBC | - Thermal Barrier Coating |
| WC | - With Coating |
| WOC | - Without Coating |

# Developing a Decision Support System for the Selection of Appropriate Procurement Method for A Building Project In Nigeria

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AINA Omotayo Olugbenga[2]

GJRE Classification (FOR)
E 090502

***Abstract*** **–In an industry where the choice of a procurement method is haphazard, developing a decision support system to guide clients in their choices is needed. This research work was aimed at developing a framework using the multi-attribute utility approach. Public clients' prioritized factors for cost categories of building types and the suitability of a procurement method achieving a selection criterion (utility coefficients) were established. Then using the weighted sum model (i.e. additive utility), the procurement method with the largest preference value was determined for each cost category and building type. The model revealed that, for a residential project of up to N100 million (Naira) cost category, taken into consideration public clients' priority rating, design – bid – construct (D-B-C) was the most appropriate procurement option. A trend emerged that for a building project of up to N100 million (Naira), the design – bid-construct, was the most appropriate for all building types. While for a building project of above N500 million (Naira), the management contracting was the most appropriate procurement option for all building types.**

*Keywords*-decision support system, procurement, multi-attribute utility building project, Nigeria.

## I. Introduction

The decision to select the appropriate procurement option to implement a construction project is crucial. Though it does not necessary lead to a successful project but with other factors taken into consideration can influence the success of the project. But in Nigeria, clients and consultants as observed by Ojo (1999), do not have a specific procedure in choosing their procurement method to implement projects but base it on familiarity with a particular method. Hence clients use procurement methods compatible with their corporate environments. So public clients in Nigeria use the design – bid- construct (traditional contracting method) because of public accountability while private clients use the design - build because they do not have the relevant experts for design and supervision. As observed by Masterman (1992), the way many clients choose their procurement methods to implement projects Lacks logic. This is as a result of the fact that there, is no theoretical framework on which to derive either an ideal or an optimum approach to procurement (Rwelamia, et al. 2000).

The benefits of implementing projects using the appropriate procurement method are to both the client and the nation. According to Kumaraswamy and Dissanayaka, (1998) it could lead to longer terms benefits through the development and upgrading of domestic contractors and other construction organizations. This has been the cases in Malaysia, Singapore, Sri-Lanka and Australia. (Abdul-Aziz and Ofori, 1996; Ofori, 1996; Kumaraswamy and Dissanayaka, 1997 and Sidwell, 1997) respectively. This strategic change in procurement practices and procedure is inevitable in the Nigerian construction industry. Okpala (2000) saw this need and suggested a complete overhaul of the existing construction industry's framework if the industry is to survive in the present Nigerian ailing economy. The aim of this research work was to develop such a framework. The weighted sum model of the multi-attribute utility approach (MAUA) was used to match clients' prioritized factors with the benchmarked performance of the procurement methods in achieving a selection criterion (utility coefficient), to select appropriate procurement method for a building project.

## II. Multi-Attribute Utility Approach

Since NEDO's (1985) suggestion that, client and advisers could rate the different procurement options using client's priority, many researchers have developed different approaches to procurement selection. These approaches vary from the simple rating system to a more complex multi-attribute, the analytical hierarchical process and matrix based approaches. According to Ng et al. (2002), these approaches have been proposed to overcome identified weaknesses of the selection practices.

The multi-attribute utility approach (MAUA) is used mostly to solve complex problems that involve the consideration of several criteria in relation to different outcomes. The decision makers assess the value of possible outcomes based on utility i.e. relative desirability of each possible outcome (Fellows et al; 1983) the MAUA is developed where the expected utility of choice j is

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determined by:

$$Uj = \sum_{i=x_i}^{n} wijxi \quad (1)$$

Source: Chang and Ive (2002)

Where xi is the value given to the attribute i of utility function decided by the decision maker's subjective evaluation and wij is the utility coefficients relating attributes to options (Chang and Ive, 2002). Fellows et al. (1983) opined that, the MAUA could be used as a tool to measure objectivity in an otherwise subjective area of management. Love et al. (1998) regarded it as the foremost technique appropriate for examining the criteria of clients and preferences of experts' weights. As applied to construction management, it involves four steps: (Chang and Ive, 2002).

Identification of priority variables (i.e. criteria);

Fixing of utility factors by experts relating achievement of priority variables as outcomes to procurement routes;

Determination of relative importance attached to each criterion and

Summing up the weighted priority variables of each procurement route and choosing the one with highest score.

Chan (1995), Love et al. (1998); Ambrose and Tucker (2000) all used the idea of MAUA to develop models to aid practitioners select the most appropriate procurement system in Australia. Similarly, Kumaraswamy and Dissanayaka (1998) and Chan et al. (2001) applied the MAUA to guide clients in the Hong kong construction industry choose the most appropriate procurement method.

## III. Data Collection Procedure

A survey instrument in the form of questionnaire was used to capture the necessary data in this study. Clients (public and private) and consultants who are involved in the decision of choosing a procurement method were asked to identify the criteria they consider in their choice of a procurement method. In addition they were asked to prioritize these criteria based on the type of building and cost. The project types considered were residential, office and commercial buildings. These were categorized into N10 million (Naira) – N100 million (Naira), N101 million (Naira) – N500 million (Naira) and above N500 million (Naira). Respondents were asked to indicate their priority preferences of the selection criteria on a 5- point scale; 1 – "not important" to 5 – "very important". The reliability of the five – point Likert scale was tested using Cronbach α of the SPSS package at 5% significant level. Also Kendall's coefficient of concordance test was used to determine the degree of agreement of rankings within groups. The selection criteria considered were speed, cost certainty, time certainty, price competition, quality, risk avoidance (in the event of time slippage) and risk avoidance (in the event of cost slippage). Results of the prioritization (i.e. the relative importance attached to these criteria) of these criteria based on the type of building and cost categories were as published in Ojo (2009a). These criteria were identified and priorized by senior managers of 13 public clients establishments and 26 private clients establishments.

In a further research, respondents (clients, consultants and contractors) were asked to rate the suitability of procurement options in achieving a selection criterion based on cost categories using a Likert scale of 1 to 10. A rating of 1 means, low suitability in achieving a selection criterion and 10 means, very high suitability in achieving a selection criterion. The procurement options considered were those in use in Nigeria such as design – bid- construct; design – build system, management contracting, direct labour system and build – Own – Operate – Transfer (BOOT). The benchmark performance values (aij) of these procurement options against the selection criteria were as published in Ojo (2009b). For details on questionnaires distributed and the number of correctly completed questionnaire among the three classes of respondents, see Ojo (2009b).

## IV. Data Analysis, Results and Discussion

Considering a decision – making problem with M alternatives and N criteria whereby the alternatives is denoted as:

Ai (for i = 1, 2, 3,M) and criteria as Cj (for j = 1, 2, 3, …….. N). It is assumed (Trianbtapyllou et al, 1997) that the decision maker knows the performance values aij (for i = 1, 2, 3, M and j = 1, 2, 3, N) of each of the alternatives in terms of each of the decision criterion. Also that for each decision criterion, the decision maker has determined its relative importance denoted as Cj (for j = 1, 2, 3, N). lastly that the relative importance of the N criteria satisfies the following normalization constraint:

$$\sum_{j=i}^{n} Cj = 1 \quad (2)$$

This is termed the rationalized priority rating and is calculated as:

$$Cj = \frac{RI_P}{\sum_{P=1}^{K} (RI_P)} \quad (3)$$

Where $RI_P$ – is the relative importance index.

It is used to calculate the performance of the alternatives by an additive utility (the weighted sum model) of the

following form:

$$Pi = \sum_{j=i}^{n} aijCj \qquad (4)$$

For i = 1, 2, 3, …… M where Pi is the preference value of alternatives

Ai (i=1, 2, 3, m) when all the criteria are considered simultaneously. For maximization case (as in this study) the best alternative is the one which has the largest preference value.

For illustration and constraint of space, the rationalized priority rating by public clients only is published as in Table i in this study. (NOTE: The fuller results are being used to develop a computer soft ware to select a procurement method).

**Table I: Rationalized Priority Rating By Public Clients**

| Selection criteria | Residential (Multi-Unit Housing) | | | Office | | | Commercial | | |
|---|---|---|---|---|---|---|---|---|---|
| | 10m – 100m | 101m – 500m | Above 500m | 10m – 100 m | 101m – 500m | Above 500m | 10m – 100m | 101m - 500m | Above 500m |
| 1. Speed | 0.15 | 0.16 | 0.15 | 0.15 | 0.16 | 0.15 | 0.16 | 0.15 | 0.15 |
| 2. Cost certainty | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 |
| 3. Time Certainty | 0.14 | 0.14 | 0.14 | 0.15 | 0.14 | 0.14 | 0.15 | 0.15 | 0.14 |
| 4. Price competition | 0.12 | 0.11 | 0.12 | 0.13 | 0.11 | 0.11 | 0.12 | 0.11 | 0.12 |
| 5. Quality | 0.17 | 0.16 | 0.16 | 0.17 | 0.16 | 0.17 | 0.16 | 0.16 | 0.16 |
| 6. Risk Avoidance (Time) | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.13 | 0.14 | 0.14 |
| 7. Risk Avoidance (Cost) | 0.13 | 0.14 | 0.14 | 0.12 | 0.14 | 0.14 | 0.13 | 0.14 | 0.14 |
| Totals | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

*Source: Field Survey (2006).*

The weighted sum model results for residential, office and commercial projects based on cost categories are as in Tables ii, iii, iv, v, vi, vii, viii, ix and x respectively

**Table II: The Weighted Sum Model Results for Residential Projects Costing N10 Million – N100million by Public Clients.**

| | | A | | B | | C | | D | | E | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Selection criteria** | **Cj** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** |
| Speed | 0.15 | 9.1 | 1.37 | 8.0 | 1.20 | 7.7 | 1.16 | 8.6 | 1.29 | 6.7 | 1.01 |
| Cost certainty | 0.15 | 8.2 | 1.23 | 8.5 | 1.28 | 8.0 | 1.20 | 7.9 | 1.19 | 5.7 | 0.86 |
| Time certainty | 0.14 | 7.9 | 1.11 | 7.7 | 1.08 | 8.8 | 1.23 | 9.3 | 1.30 | 9.0 | 1.26 |
| Price competition | 0.12 | 8.0 | 0.96 | 7.7 | 0.92 | 7.4 | 0.89 | 5.8 | 0.70 | 4.7 | 0.56 |
| Quality | 0.17 | 8.6 | 1.46 | 8.7 | 1.48 | 8.9 | 1.51 | 9.1 | 1.55 | 9.3 | 1.58 |
| Risk avoidance (time) | 0.14 | 8.1 | 1.13 | 8.0 | 1.12 | 8.0 | 1.12 | 8.3 | 1.16 | 8.7 | 1.22 |
| Risk avoidance (cost) | 0.13 | 8.0 | 1.04 | 7.3 | 0.95 | 8.2 | 1.07 | 7.9 | 1.03 | 7.7 | 1.00 |
| Totals | 1.00 | | 8.30 | | 8.03 | | 8.18 | | 8.22 | | 7.49 |
| Rank Order | | | 1 | | 4 | | 3 | | 2 | | 5 |

*Source: Field Survey (2006).*

Legend: A – D-B-C, B – Design-Build
C – Management Contracting, D – Direct Labour
E - BOOT
Cj – Rationalized Priority Rating
aij – Utility factor of each procurement method

**Table III: The Weighted Sum Model Results for Residential Projects Costing N101 Million – N500million by Public Clients**

| | | A | | B | | C | | D | | E | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Selection criteria** | **Cj** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** |
| Speed | 0.16 | 9.1 | 1.46 | 7.6 | 1.22 | 7.8 | 1.25 | 8.1 | 1.30 | 6.7 | 1.07 |
| Cost certainty | 0.15 | 7.9 | 1.19 | 8.4 | 1.26 | 8.7 | 1.31 | 7.8 | 1.17 | 5.7 | 0.86 |
| Time certainty | 0.14 | 7.6 | 1.06 | 8.0 | 1.12 | 8.5 | 1.19 | 8.6 | 1.20 | 9.0 | 1.26 |
| Price competition | 0.11 | 8.0 | 0.88 | 7.8 | 0.86 | 8.3 | 0.91 | 6.1 | 0.67 | 4.7 | 0.52 |
| Quality | 0.16 | 8.4 | 1.34 | 8.8 | 1.41 | 9.2 | 1.47 | 8.4 | 1.34 | 9.3 | 1.49 |
| Risk avoidance (time) | 0.14 | 8.4 | 1.18 | 8.2 | 1.15 | 8.8 | 1.23 | 7.7 | 1.08 | 8.7 | 1.22 |
| Risk avoidance (cost) | 0.14 | 8.4 | 1.18 | 7.6 | 1.06 | 8.5 | 1.19 | 6.9 | 0.97 | 7.7 | 1.08 |
| Totals | 1.00 | | 8.29 | | 8.08 | | 8.55 | | 7.73 | | 7.50 |
| Rank Order | | | 2 | | 3 | | 1 | | 4 | | 5 |

*Source: Field Survey (2006).*

Legend: A – D-B-C, B – Design-Build
C – Management Contracting, D – Direct Labour
E - BOOT
Cj – Rationalized Priority Rating
aij – Utility factor of each procurement method

**Table IV: The Weighted Sum Model Results For Residential Projects Costing N500million Above By Public Clients**

| | | A | | B | | C | | D | | E | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Selection criteria** | **Cj** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** |
| Speed | 0.15 | 9.2 | 1.38 | 8.8 | 1.32 | 8.0 | 1.20 | 8.5 | 1.28 | 6.7 | 1.01 |
| Cost certainty | 0.15 | 8.8 | 1.32 | 8.6 | 1.29 | 8.7 | 1.31 | 7.7 | 1.16 | 5.3 | 0.80 |
| Time certainty | 0.14 | 8.2 | 1.15 | 8.2 | 1.15 | 8.8 | 1.23 | 9.2 | 1.29 | 9.0 | 1.26 |
| Price competition | 0.12 | 8.2 | 0.98 | 8.0 | 0.96 | 8.5 | 1.02 | 5.8 | 0.70 | 4.7 | 0.56 |
| Quality | 0.16 | 9.0 | 1.44 | 9.0 | 1.44 | 9.5 | 1.52 | 8.8 | 1.41 | 9.3 | 1.49 |
| Risk avoidance (time) | 0.14 | 7.7 | 1.08 | 8.4 | 1.18 | 8.8 | 1.23 | 7.7 | 1.08 | 8.7 | 1.22 |
| Risk avoidance (cost) | 0.14 | 8.7 | 1.22 | 7.8 | 1.09 | 8.5 | 1.19 | 7.5 | 1.05 | 8.0 | 1.12 |
| Totals | 1.00 | | 8.57 | | 8.43 | | 8.70 | | 7.97 | | 7.46 |
| Rank Order | | | 2 | | 3 | | 1 | | 4 | | 5 |

*Source: Field Survey (2006).*

Legend: A – D-B-C, B – Design-Build
C – Management Contracting, D – Direct Labour
E - BOOT
Cj – Rationalized Priority Rating
aij – Utility factor of each procurement method

**Table V: The Weighted Sum Model Results for Office Projects Costing N10 Million – N100 Million by Public Clients**

| | | A | | B | | C | | D | | E | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Selection criteria** | **Cj** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** |
| Speed | 0.15 | 9.1 | 1.37 | 8.0 | 1.20 | 7.7 | 1.16 | 8.6 | 1.29 | 6.7 | 1.01 |
| Cost certainty | 0.15 | 8.2 | 1.23 | 8.5 | 1.28 | 8.0 | 1.20 | 7.9 | 1.19 | 5.7 | 0.86 |
| Time certainty | 0.15 | 7.9 | 1.19 | 7.7 | 1.16 | 8.8 | 1.32 | 9.3 | 1.40 | 9.0 | 1.35 |
| Price competition | 0.13 | 8.0 | 10.4 | 7.7 | 1.00 | 7.4 | 0.96 | 5.8 | 0.75 | 4.7 | 0.61 |
| Quality | 0.17 | 8.6 | 1.46 | 8.7 | 1.48 | 8.9 | 1.51 | 9.1 | 1.55 | 9.3 | 1.58 |
| Risk avoidance (time) | 0.14 | 8.1 | 1.13 | 8.0 | 1.12 | 8.0 | 1.12 | 8.3 | 1.16 | 8.7 | 1.22 |
| Risk avoidance (cost) | 0.12 | 8.0 | 0.96 | 7.3 | 0.88 | 8.2 | 0.98 | 7.9 | 0.95 | 7.7 | 0.92 |
| Totals | 1.00 | | 8.38 | | 8.12 | | 8.25 | | 8.29 | | 7.55 |
| Rank Order | | | 1 | | 4 | | 3 | | 2 | | 5 |

*Source: Field Survey (2006).*

Legend: A – D-B-C, B – Design-Build
C – Management Contracting, D – Direct Labour
E - BOOT
Cj – Rationalized Priority Rating

**Table VI: The Weighted Sum Model Results for Office Projects Costing N101 Million – N500 Million by Public Clients**

| | | A | | B | | C | | D | | E | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Selection criteria** | **Cj** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** |
| Speed | 0.16 | 9.1 | 1.46 | 7.6 | 1.22 | 7.8 | 1.25 | 8.1 | 1.30 | 6.7 | 1.07 |
| Cost certainty | 0.16 | 7.9 | 1.26 | 8.4 | 1.34 | 8.7 | 1.39 | 7.8 | 1.25 | 5.7 | 0.91 |
| Time certainty | 0.14 | 7.6 | 1.06 | 8.0 | 1.12 | 8.5 | 1.19 | 8.6 | 1.20 | 9.0 | 1.26 |
| Price competition | 0.11 | 8.0 | 0.88 | 7.8 | 0.86 | 8.3 | 0.91 | 6.1 | 0.67 | 4.7 | 0.52 |
| Quality | 0.16 | 8.4 | 1.34 | 8.8 | 1.41 | 9.2 | 1.47 | 8.4 | 1.34 | 9.3 | 1.49 |
| Riskavoidance (time) | 0.14 | 8.4 | 1.18 | 8.2 | 1.15 | 8.8 | 1.23 | 7.7 | 1.08 | 8.7 | 1.22 |
| Risk avoidance (cost) | 0.14 | 8.3 | 1.16 | 7.6 | 1.06 | 8.5 | 1.19 | 6.9 | 0.97 | 7.7 | 1.08 |
| Totals | 1.00 | | 8.34 | | 8.16 | | 8.63 | | 7.81 | | 7.55 |
| Rank Order | | | 2 | | 3 | | 1 | | 4 | | 5 |

*Source: Field Survey (2006).*

Legend: A – D-B-C, B – Design-Build
C – Management Contracting, D – Direct Labour
E - BOOT
Cj – Rationalized Priority Rating
aij – Utility factor of each procurement method

**Table VII: The Weighted Sum Model Results For Office Projects Costing N500 Million Above By Public Clients.**

| | | A | | B | | C | | D | | E | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Selection criteria** | **Cj** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** |
| Speed | 0.15 | 9.2 | 1.38 | 8.8 | 1.32 | 8.0 | 1.20 | 8.5 | 1.28 | 6.7 | 1.01 |
| Cost certainty | 0.15 | 8.8 | 1.32 | 8.6 | 1.29 | 8.7 | 1.31 | 7.7 | 1.16 | 5.3 | 0.80 |
| Time certainty | 0.14 | 8.2 | 1.15 | 8.2 | 1.15 | 8.8 | 1.23 | 9.2 | 1.29 | 9.0 | 1.26 |
| Price competition | 0.11 | 8.2 | 0.90 | 8.0 | 0.88 | 8.5 | 0.94 | 5.8 | 0.64 | 4.7 | 0.52 |
| Quality | 0.17 | 9.0 | 1.53 | 9.0 | 1.53 | 9.5 | 1.62 | 8.8 | 1.50 | 9.3 | 1.58 |
| Riskavoidance (time) | 0.14 | 7.7 | 1.08 | 8.4 | 1.18 | 8.8 | 1.23 | 7.7 | 1.08 | 8.7 | 1.22 |
| Risk avoidance (cost) | 0.14 | 8.7 | 1.22 | 7.8 | 1.09 | 8.8 | 1.23 | 7.5 | 1.05 | 8.0 | 1.12 |
| Totals | 1.00 | | 8.58 | | 8.44 | | 8.76 | | 8.00 | | 7.51 |
| Rank Order | | | 2 | | 3 | | 1 | | 4 | | 5 |

*Source: Field Survey (2006).*

Legend: A – D-B-C, B – Design-Build
C – Management Contracting, D – Direct Labour
E - BOOT
Cj – Rationalized Priority Rating
aij – Utility factor of each procurement method

**Table VIII: The Weighted Sum Model Results for Commercial Projects Costing N10 Million – N100 Million by Public Clients**

| Selection criteria | Cj | A aij | A Result | B aij | B Result | C aij | C Result | D aij | D Result | E aij | E Result |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Speed | 0.16 | 9.1 | 1.46 | 8.0 | 1.28 | 7.7 | 1.23 | 8.6 | 1.38 | 6.7 | 1.07 |
| Cost certainty | 0.15 | 8.2 | 1.23 | 8.5 | 1.28 | 8.0 | 1.20 | 7.9 | 1.19 | 5.7 | 0.86 |
| Time certainty | 0.15 | 7.9 | 1.19 | 7.7 | 1.16 | 8.8 | 1.32 | 9.3 | 1.40 | 9.0 | 1.35 |
| Price competition | 0.12 | 8.0 | 0.96 | 7.7 | 0.92 | 7.4 | 0.89 | 5.8 | 0.70 | 4.7 | 0.56 |
| Quality | 0.16 | 8.6 | 1.38 | 8.7 | 1.39 | 8.9 | 1.42 | 9.1 | 1.46 | 9.3 | 1.49 |
| Riskavoidance (time) | 0.13 | 8.1 | 1.05 | 8.0 | 1.04 | 8.0 | 1.04 | 8.3 | 1.08 | 8.7 | 1.13 |
| Risk avoidance (cost) | 0.13 | 8.0 | 1.04 | 7.3 | 0.95 | 8.2 | 1.07 | 7.9 | 1.03 | 7.7 | 1.00 |
| Totals | 1.00 | | 8.31 | | 8.02 | | 8.17 | | 8.24 | | 7.46 |
| Rank Order | | | 1 | | 4 | | 3 | | 2 | | 5 |

*Source: Field Survey (2006).*

Legend: A – D-B-C, B – Design-Build
C – Management Contracting, D – Direct Labour
E - BOOT
Cj – Rationalized Priority Rating
aij – Utility factor of each procurement method

**Table IX: The Weighted Sum Model Results For Commercial Projects Costing N101 Million – N500 Million By Public Clients**

| | | A | | B | | C | | D | | E | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Selection criteria** | **Cj** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** |
| Speed | 0.15 | 9.1 | 1.37 | 7.6 | 1.14 | 7.8 | 1.17 | 8.1 | 1.22 | 6.7 | 1.01 |
| Cost certainty | 0.15 | 7.9 | 1.19 | 8.4 | 1.26 | 8.7 | 1.31 | 7.8 | 1.17 | 5.7 | 0.86 |
| Time certainty | 0.15 | 7.6 | 1.14 | 8.0 | 1.20 | 8.5 | 1.28 | 8.6 | 1.29 | 9.0 | 1.35 |
| Price competition | 0.11 | 8.0 | 0.88 | 7.8 | 0.86 | 8.3 | 0.91 | 6.1 | 0.67 | 4.7 | 0.52 |
| Quality | 0.16 | 8.4 | 1.34 | 8.8 | 1.41 | 9.2 | 1.47 | 8.4 | 1.34 | 9.3 | 1.49 |
| Riskavoidance (time) | 0.14 | 8.4 | 1.18 | 8.2 | 1.15 | 8.8 | 1.23 | 7.7 | 1.08 | 8.7 | 1.22 |
| Risk avoidance (cost) | 0.14 | 8.3 | 1.16 | 7.6 | 1.06 | 8.5 | 1.19 | 6.9 | 0.97 | 7.7 | 1.08 |
| Totals | 1.00 | | 8.26 | | 8.08 | | 8.56 | | 7.74 | | 7.53 |
| Rank Order | | | 2 | | 3 | | 1 | | 4 | | 5 |

*Source: Field Survey (2006).*

Legend: A – D-B-C, B – Design-Build
C – Management Contracting, D – Direct Labour
E - BOOT
Cj – Rationalized Priority Rating
aij – Utility factor of each procurement method

**Table X: The Weighted Sum Model Results For Commercial Projects Costing N500 Million Above By Public Clients**

| | | A | | B | | C | | D | | E | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Selection criteria** | **Cj** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** | **aij** | **Result** |
| Speed | 0.15 | 9.2 | 1.38 | 8.8 | 1.32 | 8.0 | 1.20 | 8.5 | 1.28 | 6.7 | 1.01 |
| Cost certainty | 0.15 | 8.8 | 1.32 | 8.6 | 1.29 | 8.7 | 1.31 | 7.7 | 1.16 | 5.3 | 0.80 |
| Time certainty | 0.14 | 8.2 | 1.15 | 8.2 | 1.15 | 8.8 | 1.23 | 9.2 | 1.29 | 9.0 | 1.26 |
| Price competition | 0.12 | 8.2 | 0.98 | 8.0 | 0.96 | 8.5 | 1.02 | 5.8 | 0.70 | 4.7 | 0.56 |
| Quality | 0.16 | 9.0 | 1.44 | 9.0 | 1.44 | 9.5 | 1.52 | 8.8 | 1.41 | 9.3 | 1.49 |
| Riskavoidance (time) | 0.14 | 7.7 | 1.08 | 8.4 | 1.18 | 8.8 | 1.23 | 7.7 | 1.08 | 8.7 | 1.22 |
| Risk avoidance (cost) | 0.14 | 8.7 | 1.22 | 7.8 | 1.09 | 8.8 | 1.23 | 7.5 | 1.05 | 8.0 | 1.12 |
| Totals | 1.00 | | 8.57 | | 8.43 | | 8.74 | | 7.97 | | 7.46 |
| Rank Order | | | 2 | | 3 | | 1 | | 4 | | 5 |

*Source: Field Survey (2006).*

Legend: A – D-B-C, B – Design-Build
C – Management Contracting, D – Direct Labour
E - BOOT
Cj – Rationalized Priority Rating
aij – Utility factor of each procurement method

The weighted sum model results by public clients revealed that, for a residential project of up to N100 million (Naira) cost and taken into consideration their priority rating, D-B-C was the most appropriate procurement option. Direct labour system was ranked second most appropriate. It means that if a client has a supervisory outfit, then he can consider the direct labour option. BOOT system was ranked the least appropriate for residential projects of up to N100 million (Naira) cost. For residential projects of N101 million (Naira) – N500 million (Naira) cost range, management contracting was the "best in class" i.e. the most appropriate to implement projects of that cost range. The D-B-C was ranked second while BOOT system was the least appropriate. As regards residential projects of above N500 million (Naira), management contracting was the most appropriate procurement option. Again, the D-B-C was ranked second and BOOT system the least appropriate.

For office projects of N10 million (Naira) – N100 million (Naira) cost, the weighted sum model results by public clients showed that, D-B-C was "best in class" followed by direct labour system. BOOT system was the least appropriate. For projects of up to N101 million (naira) – N500 million (naira) cost, management contracting was ranked the most appropriate procurement option, D-B-C as second while BOOT system was the least appropriate. As regards office projects of above N500 million (Naira), management contracting was the "best in class" followed by D-B-C while BOOT system, the least appropriate. The weighted sum model results by public clients revealed that for commercial projects of up to N100 million (Naira), D-B-C was the most appropriate. Direct labour system was ranked second while BOOT system, the least appropriate. For commercial projects of 101 million (Naira) – N500 million (Naira) cost range, management contracting was the "best in class", followed by D-B-C. The BOOT system was ranked the least appropriate for this cost range. As regards commercial projects of above N500 million (Naira), management contracting was the most appropriate and D-B-C second best. BOOT system was ranked the least

Appropriate. In an open-ended question public clients were asked to indicate which procurement option they would prefer to use to implement projects of the cost categories based on their priority rating. For projects of up to N100million (Naira) cost, majority of the public clients indicated D-B-C. The need for adequate management of design and construction stages informed their choice. As for projects of N101 million (Naira) – N500 million (Naira) cost range, 50% of public clients would prefer the use of management contracting as compared to 32.2% who preferred the D-B-C. And for project cost of above N500 million (Naira) public clients would prefer either the use of D-B-C or the management contracting.

## V. Conclusions

A general trend emerged from the results of the weighted sum model by public clients. The trend was that, for a building project of up to N100 million (Naira) cost, public clients would have to use the D-B-C based on their priority rating. However, for building projects from N101 million (Naira) and above, the management contracting emerged as the most appropriate procurement option based on their priority rating. But because the Nigerian public service does not allow the use of management contracting public clients would have to use the D-B-C as their preference indicated.

## VI. References


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# Prediction of Elemental Sulphur Saturation around the Wellbore

GJRE Classification (FOR)
C 090403, 090499, 090499, 090406

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***Abstract*- Sour gas reservoirs with high content of hydrogen sulfide are distributed widely around the world. Solid elemental sulfur which dissolves in the gas phase originally in the reservoir in form of sulphur compound, may deposit when the thermodynamic conditions of the temperature, pressure or composition changes in the process of production. Deposition of solid elemental sulfur may block the pores in the formation and significantly affect the gas deliverability.**

**Robert Bruce model has been exploited to describe the phenomenon of elemental suphur induced flow impairment and the key factors that influence the magnitude around the well bore region. Previous model assumed constant porosity damage factor, which is the function of variable parameters that govern magnitude of flow impairment induced by elemental suphur.**

**This study presented an improved analytical model for predicting elemental sulphur build up rate around the well bore. Results show that the previous model under-estimated elemental sulphur build up rate at different radial distance around the wellbore while the minimum blockage time was over-estimated.**

## I. Introduction

Sulphur compounds are considered as the most hazardous non-hydrocarbons in reservoir fluids, because of their corrosive nature, their deleterious effects of petroleum products, their tendency to plug porous medium which may impair formation productivity, their effect on oxidation characteristics, and their disagreeable odor.

Studies have shown that almost all deep sour reservoirs precipitate elemental sulphur either occurring as a result of decomposition of $H_2S$ to give elemental sulphur or occurring as indigenous usually referred to as native sulphur as a dissolved species. Precipitation of this native (elemental) sulphur occurs as a result of thermodynamic changes in the reservoir during production. Elemental sulphur is often present in sour gases and/or crude oils in appreciable quantities at reservoir condition. Variation in reservoir condition of pressure and temperature that occurs below sulphur saturated state causes sulphur deposition.

Precipitation and deposition of elemental sulphur within reservoirs, in the near-wellbore area may significantly reduce the inflow performance of sour-gas wells and thus affect economic feasibility negatively[4]. Formation damage which is the inevitable end effect of the precipitation of elemental sulphur is defined as obstructions occurring in the Near-wellbore region of the rock matrix primarily as a result of permeability reduction. Many of the operational and reservoir parameters influence sulphur deposition have been identified by Hyne [9-11].

Most of the reported investigations related to sulphur deposition have focused on deposition in the well, while few studies have been reported on the effect of deposition within the formation. Among other investigators, Kuo (1966)[2] investigated the effect of the deposition of immobile elemental sulphur from a homogeneous reservoir within a fluid containing 78% $H_2S$ and an estimated sulphur content of 120g/m$^3$. Field results have also been reported by Chernik and Williams (1993)[13] for the effect of mobile liquid sulphur deposit on the productivity of the high $H_2S$ (>90%) content Bearberry (Alberta, Canada) sour gas reservoir. Bruce E. Roberts (1997)[1] focused on a more conventional sour gas reservoir with $H_2S$ concentrations less than 25% and equilibrium sulphur content of the reservoir fluid at these concentrations of $H_2S$ generally less than 2g/m$^3$. Investigation carried out by Shedid A. Shedid and Zekri Y. Abdulrazag (2002)[15] presented an experimental approach on elemental sulphur deposition in carbonate oil reservoirs with results that showed the influences of oil flow rate, initial sulphur concentration of crude oil, and reservoir rock permeability on elemental sulphur plugging in carbonate oil reservoirs.

This paper presents an improved model of Robert Bruce (1997) formulation on elemental sulphur saturation at different radial distance away from the well bore. His formulation was modified by incorporating effect of porosity damage function which was overlooked his model.

## II. Model Formulation

The following assumptions will be made use of so as to enable simplicity in developing a simple analytical model:

Viscosity is assumed constant.

Gas formation volume factor is assumed constant.

Sulphur concentration (or solubility) change with pressure is considered to be constant.

Initial condition for sulphur saturation is assumed zero i.e. $S_s$=0 @ t=0.

### *A. Developing The Analytical Model*

Considering the radial flow of gas at constant rate *q* saturated with solid state particles at a location *r* from the wellbore. Assuming the semi-steady state flow equation a pressure gradient due to pressure of solid in the flow path can be expressed as

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$$\frac{dp}{dr} = \frac{qB\mu}{2\pi rhk_a k_{r_g}} \qquad (1)$$

The fractional change in volume of solid, $dv_s$ which drops out and gets deposited in the volume element over the time interval dt is given as

$$dv_s = q.\left(\frac{dc}{dp}\right)_T dp.dt \qquad (2)$$

The deposit occupies a fractional bulk volume $dS_s$ in the porous media over an infinitesimally small radial distance increment dr, given by

$$dS_s = \frac{dV_s}{2\pi rhdr\phi_i(1-Sw_i)} \qquad (3)$$

The change in the volume of deposited sulphur as a fraction of the hydrocarbon pore volume,$dS_s$ over this time interval is given as

$$dS_s = \frac{q.\left(\frac{dc}{dp}\right)_T .\boldsymbol{dp}dt}{2\pi rh.\boldsymbol{dr}.\phi_i(1-Sw_i)} \qquad (4)$$

Incorporating equation (1) into equation (4), we have:

$$dS_s = \frac{q^2\left(\frac{dc}{dp}\right)_T B\mu dt}{4\pi^2 k_a k_r h^2.\phi_i(1-Sw_i)r^2} \qquad (5)$$

Introducing Kuo (1972) correlation on relative permeability and solid (elemental sulphur) build-up/saturation to account for effect of elemental sulphur in the flow path on effective permeability damage function

$$k_r = exp(aS_s) \qquad (6)$$

Also correcting for porosity damage function due to precipitation of elemental sulphur by incorporating the above relative permeability function given by Kuo (1972)2 into the permeability-porosity relationship given by Civan et al (1989)12 and derive a relationship between initial porosity $\phi_o$, instantaneous porosity $\phi_i$ and the elemental sulphur saturation.

$$\frac{k_{g_i}}{k_{g_o}} = \left(\frac{\phi_i}{\phi_o}\right)^3 \qquad (7)$$

As stated above using the relative permeability function

$$k_r = exp(aS_s) \qquad (8)$$

Assuming the initial condition for elemental sulphur saturation is zero i.e. Ss=0 @ t=0 k=$k_{g_o}$

$$\frac{k_{g_i}}{k_{g_o}} = \frac{k_a k_{r_i}}{k_a k_{r_o}} = exp(aS_s) = \left(\frac{\phi_i}{\phi_o}\right)^3 \qquad (9)$$

Taking the above assumptions into consideration equation (9) gives

$$exp(aS_s) = \left(\frac{\phi_i}{\phi_o}\right)^3 \qquad (10)$$

Solving equation (10) , we have:

$$\phi_i = \phi_o e^{\left(\frac{aS_s}{3}\right)} \qquad (11)$$

Substituting equation (11) into equation (5) and solve; we have:

$$\frac{dS_s}{dt} = \frac{q^2\left(\frac{dc}{dp}\right)_T B\mu}{4\pi^2 k_a h^2.\phi_o e^{\left(\frac{4aS_s}{3}\right)}(1-Sw_i)r^2} \qquad (12)$$

Eqn. 12 can be integrated subject to the initial condition that Ss=0 at t=0.

$$\int_0^{S_s} 4\pi^2 k_a h^2 r^2.\phi_o(1-Sw_i)e^{\left(\frac{4aS_s}{3}\right)} dS_s = \int_0^t q^2\left(\frac{dc}{dp}\right)_T B\mu\, dt \qquad (13)$$

Making $S_s$ the subject gives the equation that models the sulphur build – up in a reservoir at different radial distances and at given times via precipitation.

$$S_s = \frac{3}{4a} ln\left[\left(\frac{aq^2 B\mu\left(\frac{dc}{dp}\right)_T t}{3\pi^2 r^2 h^2 k_a \phi_o(1-S_{wi})}\right)+1\right] \qquad (14)$$

## III. Model Validation

Using the same data provided by Robert E. Bruce in his paper, the sulphur content of bottom-hole sample obtained before production and as determined with fluid and reservoir fluid properties for this field case is given below and is used as base-case properties for the evaluation. Table 1 and 2 show the reservoir fluid properties for this field case and data for model parameters.

**Table 1: Reservoir base case properties**

| | |
|---|---|
| Reservoir temperature | 81°C |
| Outer radius, m | 1500 |
| Effective wellbore radius @ s=-2, m | 0.74 |
| Pay thickness, m | 26 |
| Initial pressure, kPa | 36600 |
| Porosity (fraction) | 0.04 |
| Absolute permeability, md | 0.7 |
| Gas relative permeability, $k_r$ | $e^{(-6.22*Ss)}$ |
| BHP constraint, kPa | 10000 |

**Table 2: Analytical Model parameters**

| | |
|---|---|
| **B** | 0.004583 |
| **μ,** Pa.s | 0.0000228 |
| **$k_a$** | 0.7 |
| **h,** m | 26 |
| **$S_{wi}$** | 0 |
| **dc/dp**, $m^3/m^3.Pa$ | $4*10^{-15}$ |
| **a** | -6.22 |
| **$\phi$** | 0.04 |

## IV. Discussion of Results

Comparison and analysis of the results from developed model and Robert E. Bruce model shows slightly-considerable difference in the time of elemental sulphur build-up and invariably the time for complete blockage at difference radial distances from the wellbore. The results obtained from the modified model have shown that pore passage blocks faster at difference radial distances away from the wellbore compare with Robert E. Bruce model. This implied that the Robert E. Bruce model might had under-estimated elemental sulphur build up rate at different radial distance around the wellbore while the minimum blockage time might had over-estimated as report in fig 1. The results calculated for the elemental sulphur saturation and minimum blockage time at different radial distance around the wellbore, using both modified and Robert E. Bruce models respectively have been shown in table 3:

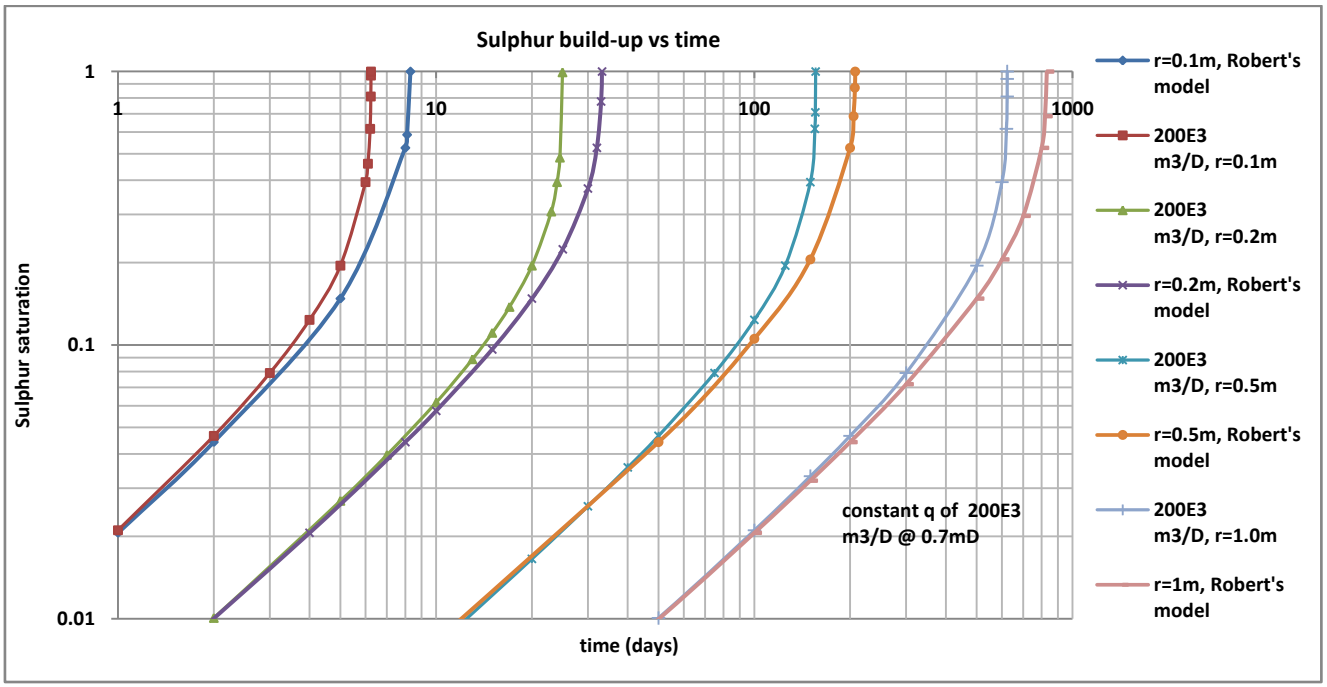


**Fig .1 Comparison of analytical model developed in this project and that developed by Robert E. Bruce to predict sulphur deposition as a function of radial distance**

| | Robert's model | | Our model | |
|---|---|---|---|---|
| r=0.1m | **t(days)** | **$S_s$** | **t(days)** | **$S_s$** |
| | | | | |
| | 1 | 0.020595608 | 1 | 0.021069017 |
| | 2 | 0.04422271 | 2 | 0.046615645 |
| | 5 | 0.147794086 | 3 | 0.079071279 |
| | 8 | 0.525369377 | 4 | 0.123616656 |
| | 8.1 | 0.586352068 | 5 | 0.195027387 |
| | **8.3** | **0.997643987** | 6 | 0.394027033 |
| | | | 6.1 | 0.459894922 |
| | | | 6.2 | 0.616347771 |
| | | | 6.23 | 0.809246428 |
| | | | 6.236 | 0.964699858 |
| | | | **6.24** | **0.997646681** |
| | | | | |
| r=0.2m | **t(days)** | **$S_s$** | **t(days)** | **$S_s$** |
| | | | | |
| | 1 | 0.004906871 | 1 | 0.004932261 |
| | 4 | 0.020595608 | 2 | 0.010074913 |
| | 8 | 0.04422271 | 5 | 0.02696636 |
| | 10 | 0.057480367 | 7 | 0.039703939 |
| | 15 | 0.096377166 | 10 | 0.061754751 |
| | 20 | 0.147794086 | 13 | 0.088761249 |
| | 25 | 0.223839273 | 15 | 0.110845564 |
| | 30 | 0.373095085 | 17 | 0.137902404 |
| | 32 | 0.525369377 | 20 | 0.195027387 |
| | 33 | 0.775643507 | 23 | 0.307339857 |
| | **33.2** | **0.997643987** | 24 | 0.394027033 |
| | | | 24.5 | 0.484073776 |
| | | | **24.94** | **0.992093409** |
| | | | | |
| r=0.5m | t(days) | $S_s$ | t(days) | $S_s$ |
| | | | | |
| | 1 | 0.000775105 | 1 | 0.000775729 |
| | 50 | 0.04422271 | 10 | 0.007991459 |
| | 100 | 0.105428372 | 20 | 0.016550391 |
| | 150 | 0.205481393 | 30 | 0.025763591 |
| | 200 | 0.525369377 | 40 | 0.035739427 |
| | 205 | 0.685798718 | 50 | 0.046615645 |
| | 207 | 0.871519281 | 75 | 0.079071279 |
| | **207.5** | **0.9976439868** | 100 | 0.123616656 |
| | | | 125 | 0.195027387 |
| | | | 150 | 0.394027033 |
| | | | 155 | 0.616347771 |
| | | | 155.5 | 0.707911565 |
| | | | **155.9** | **0.997646681** |
| | | | | |
| r=1m | **t(days)** | **$S_s$** | **t(days)** | **$S_s$** |
| | | | | |
| | 1 | 0.000193426 | 1 | 0.000193465 |
| | 50 | 0.00996823 | 50 | 0.010074913 |
| | 100 | 0.020595608 | 100 | 0.021069017 |
| | 150 | 0.031975518 | 150 | 0.033167033 |
| | 200 | 0.04422271 | 200 | 0.046615645 |
| | 300 | 0.071930343 | 300 | 0.079071279 |
| | 500 | 0.147794086 | 500 | 0.195027387 |
| | 600 | 0.205481393 | 600 | 0.394027033 |
| | 700 | 0.296315186 | 620 | 0.616347771 |
| | 800 | 0.525369377 | 623 | 0.809246428 |
| | 820 | 0.685798718 | 623.5 | 0.938850602 |
| | **830** | **0.997643987** | **623.6** | **0.997646681** |

**Table 3- Comparison between the analytical model developed and Robert's mod**

*A Effect of Permeability on Sulphur build-up in the formation*

Flowing gas at constant rate of 200E3 $m^3$/D and varying permeability (0.7md, 3.5md, 7.0md), and observing the sulphur precipitation and eventual plugging with respect to time at similar radial distances from the wellbore. The plot of elemental sulphur saturation against production time has shown in fig 2, that deposition of sulphur occurs faster in formations with lower permeability. The high permeability reservoir experiences the lower the pressure gradient and likewise the less significant the deposition of sulphur in such reservoir compare with tight gas reservoir.

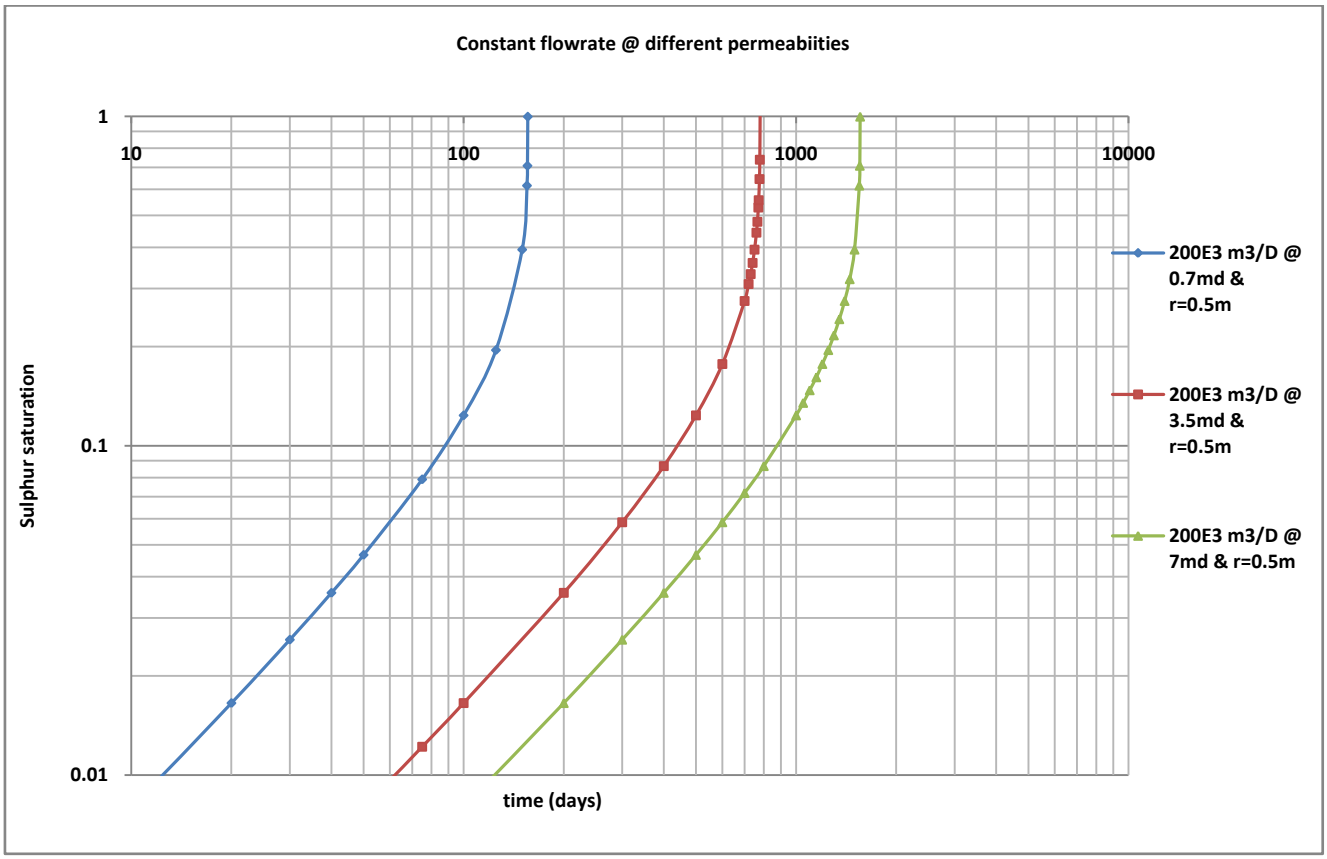


**Fig. 2 Effect of permeability on deposition of elemental sulphur (at a radial distance of *0.5m* and at a rate of *200E3 $m^3$/D*)**

*B. Effect of Flow rate on Sulphur build-up in the formation*

The effect of flow rate on sulphur deposition was investigated by varying gas flow rates at constant permeability using the modified model. In figure 3, it was noticed that saturation of sulphur at all radial distances of consideration in the formation was accelerated by increasing flow rates. The effect of variable flow rate on sulphur deposition will be made more vivid in a more permeable formation and for this reason the permeability used in this investigation was times 10 of the original formation permeability. As the gas flow rate is increased there is a proportional increase in pressure drawdown (in obedience to Darcy's law) which brings about deposition of elemental sulphur away the well bore region.

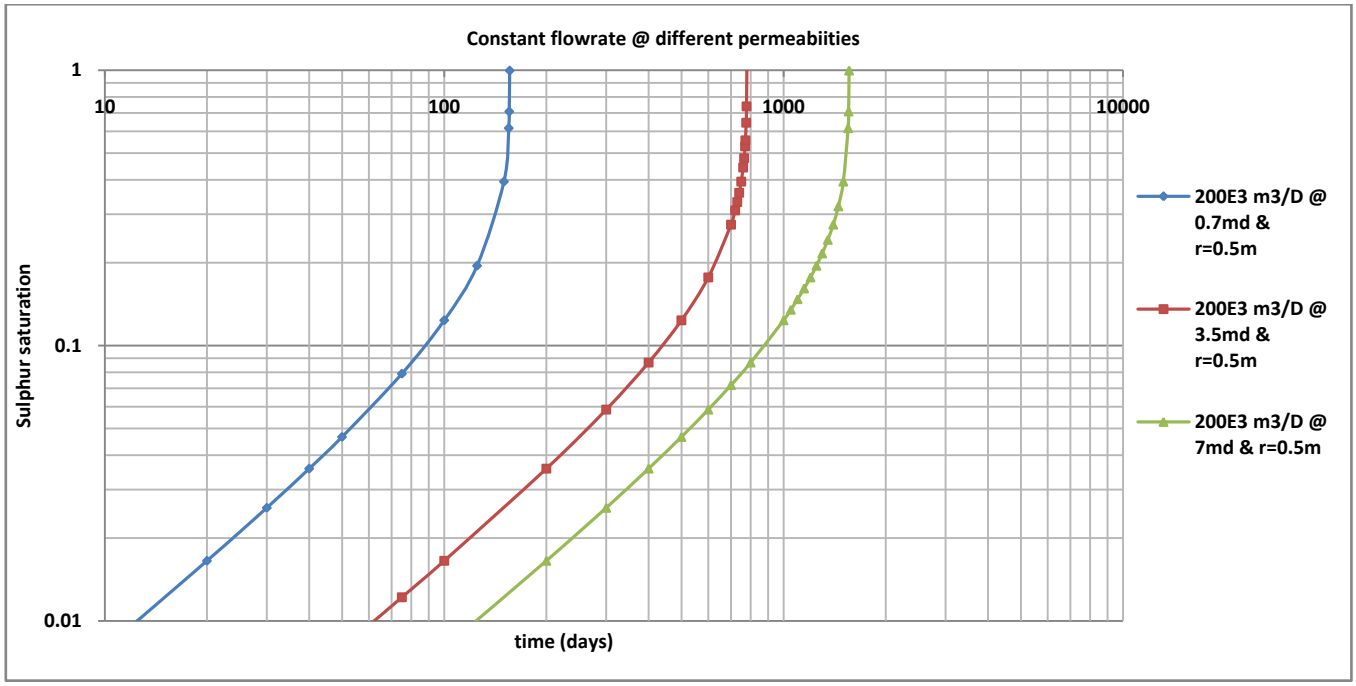


**Fig. 3. Effect of permeability on deposition of elemental sulphur (at a radial distance of *0.5m* and at a rate of *200E3 $m^3$/D*)**

## V. Conclusion

The following conclusions were drawn from the result of this study Previous model opined by Robert Bruce might had under-estimated elemental sulphur build up rate at different radial distance around the wellbore while the minimum blockage time might had over-estimated. Sulphur deposition in the formation is a near-wellbore process occurring generally within the distance range of 0.0m to 2.0m away from the well bore. Reducing the flow rate will generally increase the production time of a well before significant flow impairment by deposition of sulphur. Whether reducing the flow rate will increase the cumulative production before plugging depends on the sulphur-solubility with pressure. Also, to slow down deposition in the formation, well-stimulation techniques such as acid treatment can be carried to increase the near-wellbore permeability and this as a matter of consequence will reduce the pressure gradient which will decelerate the deposition process.

## VI. Nomenclature

| | |
|---|---|
| a | Empirical constant |
| B | Formation Volume factor, $m^3/stm^3$ |
| c | Concentration of sulphur in gas, $m^3/m^3$ |
| $\frac{dc}{dp}$ | Solubility change per unit pressure, $m^3/m^3$-Pa |
| h | Net pay thickness, m |
| $K_a$ | Absolute permeability at initial water saturation, $m^2$ |
| $k_r$ | Gas relative permeability, $m^2$ |
| q | Gas flow rate, $m^3$ |
| r | Radial distance from well, m |
| $S_s$ | Sulphur saturation relative to hydrocarbon Pore volume |
| t | Time (days) |
| $V_s$ | Volume of deposited sulphur, $m^3$ |
| $\phi$ | Instantaneous porosity |
| $\phi_i$ | Initial porosity |
| μ | Viscosity, Pa.s |

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# Two Dimension Numerical Simulation over Cylindrical Catalyst in Trickle Bed Reactor

M. Tajerian

GJRE Classification (FOR)
B 090201

***Abstract-*** **Drag coefficient determination over cylindrical catalyst is one of important problem in fluid mechanics that is different in dry or wet catalyst and is depend on wetness of catalyst. This parameter has very important role in hydrodynamics of trickle bed. In this article, it is used two dimensional numerical simulations for different region such as creeping, laminar and turbulent for drag coefficient calculation. This parameter is determined in three case: dry, wet, semi dry-semi wet for different Reynolds number from 0.007 to 10,000,000 and results is presented as curves or tables. Also the calculated parameter for dry case has good correspondence with experimental correlation.**

*Keywords*:-Drag Coefficient, Trickle Bed Reactor, Computational Fluid Dynamic, Cylindrical Catalyst

## I. Introduction

It is more than 40 years that chemical engineers have serious attention to trickle bed reactor (TBR) due to be suitable in chemical operation, oil refining, petrochemical and biochemical process. TBR especially is used when a reaction over a catalyst with two streams (gas & liquid) is existed. In table (1) a list of processes which use TBR, is presented:

**Table (1): The most application of industrial examples for TBR**

| |
|---|
| Hydro-desulfurization (HDS) - Hydro-demetalization (HDM) - Hydro-denitrogenization (HDN) - Hydro-dearomatization (HDA) |
| Catalytic Hydro-cracking - Oil Hydro-finishing |
| Acetylene selective hydrogenation for it's separation from C4 cut at butadiene presence |
| Oil hydrogenation such as carboxylic acid conversion to alcohol |
| Hydrogenation of organic acid esters for alcohol production |
| Synthesis 1,4 butene-diol (acetylene and formadehiod) |
| Formic acid oxidation in water - SO2 conversion to SO3 over activated carbon |
| Refractory organic compound oxidation in waste water over Pd catalyst by microorganism (“bio-filter). |

TBR is constituted from a long column with fixed bed and packed with solid catalyst which has cocurrent and down-flow streams. Sometimes due to system design, TBR has co-Current and up-flow streams. For modeling of liquid stream, (Crine and L'Homme, 1982). In table (2), characteristics parameters for this type of reactor is comprised with other three phase reactors.

**Table (2):Characteristics parameters of three phase reactors**

| Parameter | Stirred Slurry | TBR | Flooded Fixed Bed |
|---|---|---|---|
| Catalyst Loading %b.v. | 0.01 | 0.55-0.65 | 0.55-0.65 |
| Particle Size, mm | 0.1 | 1-5 | 1-5 |
| Catalyst Effectiveness Factor | 1 | < 1 | < 1 |
| Catalyst External Area, m2/m3 | 300-500 | 400-1500 | 400-1500 |
| Liquid Holdup | 0.8 | 0.05-0.2 | 0.4 |
| Gas Holdup | 0.2 | 0.3-0.45 | 0.1 |
| Gas-Liquid Interfacial Area, m-1 | 400 | 200-900 | 200-500 |
| Max. Reactor Pressure, MPa | 8 | Higher as possible | Higher as possible |
| Max. Reactor Vol., m3 | 50 | 150-200 | 150-200 |

The advantage of TBR are as follow: 1. High conversion reaction in reactor. 2. Minimum catalyst lost when catalyst is expensive. 3. No need to rotary section. 4. Using possibility of sever operating conditions such as high pressure and temperature. 5. Using possibility of big size of reactor. 6. Using of low ratio of liquid hold up to solid that minimize side reaction. 7. Low investment such as capital or operating costs. 8. Changing possibility of liquid flow due to parameters such as catalyst wetting and mass or heat transfer resistance.

The disadvantage of TBR is as follow: 1. Low effectiveness factor of catalyst due to using of bigger catalyst particle size. 2. Restriction in using of viscous or foaming liquid. 3. Risk ability due to high

Pressure drop or blocking of catalyst. 4. Incompletely wetting of catalyst due to low liquid flow or in low ratio of reactor diameter to catalyst particle size ( between 15 to 20). 5. Sensitive to temperature effects. 6. Severity of reaction heat recovery (Gianetto, 1992).

Hydrodynamic of TBR evaluation is essentially on the basis of reactor performance and other parameters such as

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Optimum configuration, chemical and physical interaction coefficient, pressure drop, heat and mass transfer, and energy requirements. The first goal in design is optimum gas and liquid flow rate calculation, height of column suggestion and reaction section diameter determination. For determination, more parameters is needed such as physical and chemical properties of gas and liquid streams, size and porosity of catalyst particle, ratio of diameter of column to catalyst size and so on. Hydrodynamic region for up or down flow is calculated by various experimental methods such as: pressure drop determination, thermo-conductometry tests or electro-conductometry, visual observation and so on. Down flow region in TBR is investigated extensively by researchers (Grosser,1988), (Wammes,1991), (Wild, 1991). One of the parameters in hydrodynamic of TBR is drag coefficient on catalyst. The

Calculation of drag coefficient on cylindrical catalyst (extrudated catalyst) is one of important problem in fluid mechanics (Anderson, 1995) which is different for dry or wet case and it is depend on wetting factor of catalyst. In this research, this coefficient is calculated in different region of stream and the effect of wetting parameter is evaluated. Also the effect of Reynolds number on pressure and viscous vector of drag is investigated.

## II. Problem Formulation

Regarding to high ratio of diameter to length of catalyst particle, any change in z direction will be negligible. Then for steady state, the continuity and motion equations will be as follow:

$$\frac{\partial u^*}{\partial x^*}+\frac{\partial v^*}{\partial y^*}=\circ \qquad (1)$$

$$u^*\frac{\partial u^*}{\partial x^*}+v^*\frac{\partial u^*}{\partial y^*}=-\frac{\partial P^*}{\partial x^*}+\frac{1}{\mathrm{Re}}\left(\frac{\partial^2 u^*}{\partial x^{*2}}+\frac{\partial^2 u^*}{\partial y^{*2}}\right) \qquad (2)$$

$$v^*\frac{\partial v^*}{\partial x^*}+u^*\frac{\partial v^*}{\partial y^*}=-\frac{\partial P^*}{\partial x^*}+\frac{1}{\mathrm{Re}}\left(\frac{\partial^2 v^*}{\partial x^{*2}}+\frac{\partial^2 v^*}{\partial y^{*2}}\right) \qquad (3)$$

In above equations, dimensionless terms are as follow:

$$u^*=\frac{u}{U},\quad v^*=\frac{v}{U},\quad x^*=\frac{x}{L},\quad y^*=\frac{y}{L},\quad P^*=\frac{P}{\rho U^2},\quad \mathrm{Re}=\frac{\rho UL}{\mu}$$

For dry catalyst particle in laminar and turbulent region, the non creeping condition ($u* = v* = 0$) is considered, and for wet catalyst particle the zero stress condition is used. For high Reynolds number, the ($k-\varepsilon$) standard model is considered. Total drag force has two vector of pressure and viscous as follow:

*Total Drag Force = Pressure Drag + Viscous Drag* (4)

$$\mathbf{F_t}=\int_s\int \mathbf{pn.ds}+\int_s\int \boldsymbol{\tau}.\mathbf{t.ds} \qquad (5)$$

The drag coefficient is calculated from ratio of drag force to kinetic force as follow:

$$\mathbf{C_d}=\frac{\mathbf{F_t}}{\frac{1}{2}\rho\mathbf{A}\mathbf{U}^2} \qquad (6)$$

Usually for sphere and cylinder at behind of them, separation point, reverse-flow phenomena andwake will be existed. The pressure of wake will be less than the pressure at front. Thereforeintegration of pressure over batter limit layer which give pressure drag has bigger value from viscousdrag.

## III. Numerical solution method

For calculating of flow domain over a cylinder with two dimensions, a circle or semicircle is considered and flow domain as a rectangular with steady velocity at inlet of domain is assumed (Kulkarni and moeykens, 2005). The solution stages of model are as follow:

1. Generation of suitable geometry.
2. Determination of physical properties of stream.
3. Definition of battery limit condition.
4. Solution of model for several Reynolds number.

## IV. Results analysis

CFD model solution results and experimental correlation (Ahmadi, 2005) are comprised in table (3).You can see good correspondence with experimental data. In table (4) the results from CFD model for various region are given. In this table, the drag coefficient versus Reynolds number for dry, wet and semi dry-semi wet are given and also in figure (1) as curves. As you can see, the drag coefficient has inverse correlation with Reynolds number and with increasing Reynolds number, drag coefficient is decreased. In very high value of Reynolds number this coefficient is constant and the curve will be linear. Also other important point is wetting effect on drag coefficient. According to the results the maximum value of this coefficient is in dry case and the

**Table (3): Comparison between CFD model and experimental data**

| Reynolds No. | CD ( CFD Method ) | CD ( Experimental ) |
|---|---|---|
| 0.007 | 288.75 | 274.28 |
| 0.01 | 205.8 | 216.4 |

**Table (4): Drag Coefficient versus Renolds number**

| Reynolds No. | Cd(dry) | Cd(dry & wet) | Cd(wet) |
|---|---|---|---|
| 0.007 | 288.75 | 271.10 | 252.73 |
| 0.01 | 205.8 | 182.18 | 173.73 |
| 0.1 | 21.038 | 20.881 | 18.36 |
| 1.0 | 3.463 | 3.134 | 2.839 |
| 10 | 0.8955 | 0.7774 | 0.6658 |
| 100 | 0.3739 | 0.3049 | 0.1990 |
| 1000 | 0.2584 | 0.1899 | 0.1234 |
| 2000 | 0.2492 | 0.1796 | 0.1238 |
| 3000 | 0.2522 | 0.1832 | 0.1287 |
| 4000 | 0.2450 | 0.1803 | 0.1307 |
| 10,000 | 0.2750 | 0.2287 | 0.1806 |
| 100,000 | 0.2379 | 0.2015 | 0.1810 |
| 1,000,000 | 0.2115 | 0.1884 | 0.1810 |
| 10,000,000 | 0.2001 | 0.1839 | 0.1810 |

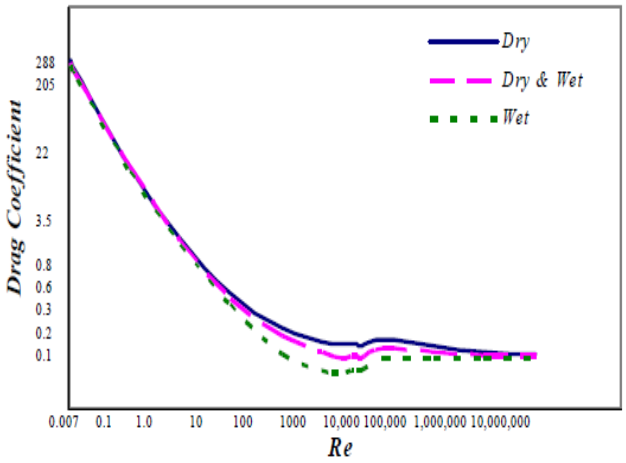


**Figure (1): Drag coefficient for dry, wet and semi dry-semi wet catalyst**

Minimum value is in wet case. Also semi dry-semi wet coefficient is between dry and wet values. Other results in this research are calculation of pressure and viscous drag for different Reynolds numbers. In table (5), the effects of pressure and viscous vectors on drag coefficient in dry catalyst are given. As you can see, the pressure vector has high effect on this coefficient and as high as Reynolds number, this effect is increased. So that in turbulent region the effect of viscous vector is negligible. The change of this value is shown in figure (2). As flow domain on cylinder in small Reynolds number is symmetric, when this number is increased the flow reach to separation point at behind of cylinder and cause to make vortex. This phenomena is investigated with various methods such as experimental or analytical. In this research, this phenomena is investigated with CFD model which in very high value Reynolds number, it is shown clearly.

**Table (5): Drag coefficient versus Reynolds number**

| Reynolds No. | Pressure Drag Coeff. | Viscous Drag Coeff. | Total Drag Coeff. |
|---|---|---|---|
| 0.007 | 145.66 | 143.09 | 288.75 |
| 0.01 | 103.82 | 101.98 | 205.8 |
| 0.1 | 10.62 | 10.418 | 21.038 |
| 1.0 | 1.76 | 1.703 | 3.463 |
| 10 | 0.5232 | 0.3722 | 0.8955 |
| 100 | 0.2888 | 0.0851 | 0.3739 |
| 1000 | 0.2342 | 0.0242 | 0.2584 |
| 2000 | 0.2316 | 0.0176 | 0.2492 |
| 3000 | 0.2342 | 0.0180 | 0.2522 |
| 4000 | 0.2340 | 0.0110 | 0.2450 |
| 10,000 | 0.2628 | 0.0122 | 0.2750 |
| 100,000 | 0.2275 | 0.0104 | 0.2379 |
| 1,000,000 | 0.2036 | 0.0079 | 0.2115 |
| 10,000,000 | 0.1924 | 0.0077 | 0.2001 |

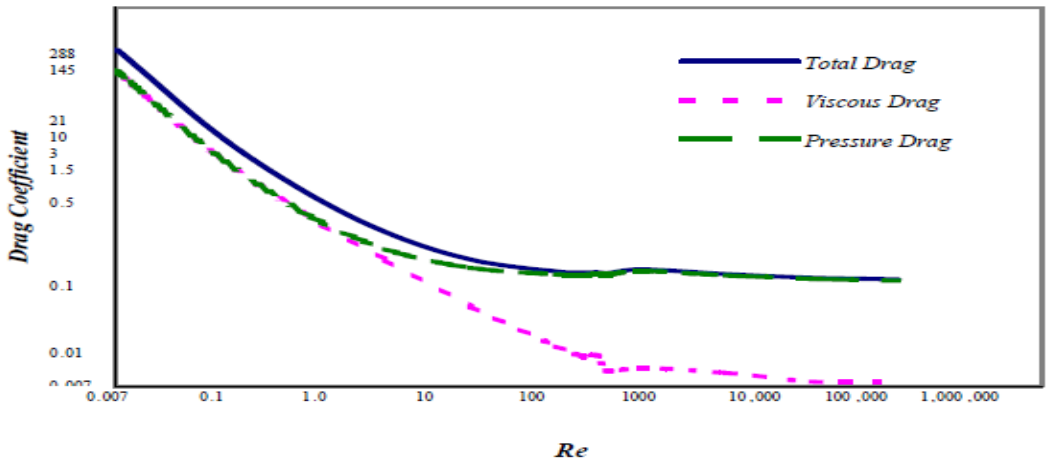


Figure (2): Reynolds number effect on pressure and viscouse drag

## V. Conclusion

In this research viscous, Pressure and total drag coefficient over a cylindrical catalyst in various Reynolds number at TBR is investigated. The Reynolds number was varied from 0.007 (creeping flow) to 10,000,000 (turbulent flow). For validation of results, the drag coefficient in creeping flow is comprised with experimental correlation (Ahmadi, 2005) which has good correspondence. After accuracy of validity for CFD model, other calculation for other Reynolds number is done. This research confirmed that with increasing velocity, the pressure drag values are higher than viscous drag and in high value Reynolds numbers, the viscous drag is negligible. Another important point in this research, is catalyst wetting effect on drag coefficient. According to figure (1) and table (4) in TBR when catalyst is completely wetted, drag coefficient has minimum value and also drag coefficient has maximum value when it is completely dry. Also as wet as catalyst, this coefficient will be smaller. Noticeable for small Reynolds numbers, between drag coefficient and wetting factor we have linear relation, so drag coefficient for semi dry-semi wet catalyst is completely average of dry and wet values.

## VI. Recommendation

The following recommendation can be useful for further investigation in this area of research:

1. Drag coefficient calculation for two particles of catalyst.

2. Role of position of two particles on drag coefficient.

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# Key Link Factor for Performance Optimization in WDM Networks with Sparse Wavelength Conversion

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GJRE Classification (FOR)
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***Abstract*** **– Blocking probability has been one of the significant parameters in the design of WDM optical networks. In most of the network topologies the probability for each link to be occupied is different. There are always some links which are more likely to be used than others which can be denoted as key links. The existing routing algorithms do not take this important factor into account significantly. The network performance deterioration is more likely caused by certain key links of the network, which is related to static factor such as particular network topology, and dynamic factors such as wavelength exhausted rate as well as the number of free wavelengths available on a link. In the proposed approach, the key links are identified based on the link usage factor of a link to minimize the capacity exhaustive blocking in WDM networks. The concept of key links is incorporated in wavelength converter placement strategies for performance optimization in WDM networks. For sparse wavelength conversion the wavelength converters are placed in the nodes that connect the key links with higher normalized frequency of usage. The performance of the proposed approach is studied for various set of wavelengths and compared over full wavelength conversion and no wavelength conversion conditions in terms of blocking probability and link utilization. The proposed approach closely tracks the performance of full wavelength conversion.**

*Keywords*-Link Utilization, Blocking probabilities, Routing and wavelength Assignment (RWA), Wavelength Division Multiplexing (WDM)

## I INTRODUCTION

Optical networks with wavelength routing are expected to form the backbone in the next generation wide area networks [1].The RWA problem is to establish a light path for each connection request and assign a wavelength to each light path such that no two light paths share a same wavelength and that the number of wavelengths used is minimized. A related optimization problem of RWA is throughput maximization problem. Performance evaluation of online algorithms for RWA was studied in [2].

The issues in wavelength routed networks include routing and wavelength assignment, minimizing the effect due to wavelength continuity constraints, design reconfiguration, Survivability of virtual topology, optical multicasting, control and management, traffic grooming, and IP over–WDM [3]. The connection requests can be either static or dynamic. The shortest-paths for each source destination pair is computed using Dijkstra's algorithm. In Dijkstra's algorithm, every link in the network is associated with a weight, for example, the propagation delay of the link. In addition to it the WDM specific information may be incorporated in the weight functions to improve the performance [4].

The concept of key links is incorporated in wavelength converter placement strategies for performance optimization in WDM networks. For sparse wavelength conversion the wavelength converters are placed in the nodes that connect the key links with higher normalized frequency of usage. The performance of the proposed approach is studied for various set of wavelengths and compared over full wavelength conversion and no wavelength conversion conditions in terms of blocking probability and link utilization.

## II SHORTEST PATH ROUTING

Here, each router periodically broadcasts its neighboring link information to all other routers. This information is used to construct the network topology with the associated link cost functions. Each router then independently computes the shortest paths from itself to every destination. When a new session request arrives, the router uses the routing table to determine the entire path from source to destination. It then attempts to assign a wavelength along this path by propagating a wavelength request to all the routers along the path. The initial wavelength may be selected randomly from one of the available wavelengths or based on other information as in [5]. If wavelength conversion is available in the network, then a light-path can be established using different wavelengths on different links. If this request fails, a different wavelength is chosen, which can be based on the feedback from the closest node on the shortest path. This process may be repeated till there is at least one wavelength available. If this fails, then the request is blocked, i.e. the light path cannot be set up. The concept of Dijkstra's algorithm may be found in [6]

### *A. Routing Algorithm*

The network topology is represented as a graph G(V, E), where V denotes the set of vertices (network nodes) and E the set of edges (links). Each link (i, j) E E is associated with

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a weight function Wij which denotes the cost of using the link. At the end of executing a shortest path algorithm such as Dijkstra's algorithm, each router has a routing table with complete path information to every destination. In WDM networks, link state information will also include WDM specific status such as number of available wavelengths, and total wavelengths. In addition, links on which all wavelengths are presently utilized may be marked as unavailable until the next routing update. Previous research has shown that weighting of links affects the blocking performance of optical networks [7].

The routes are usually considered with minimum hop counts because more scope is available for future connection requests (higher number of links are free implies higher degree of freedom). Taking the square root values offers the best performance in terms of blocking probabilities compared to other weighted functions [8]. Hsu et al. proposed a weighted-shortest path strategy, which looks for the path that minimizes the resource cost while maintaining the traffic load among the links as balanced as possible [9]. However, only the case of full wavelength conversion has been investigated.

## III LINK USAGE FACTOR

Most network topologies in actual using are irregular, so the probability for each link to be occupied is different. There are always some links are more likely to be used, which can be denoted as more "important", and at the same time some others are not. This inherent unbalance does exist but still unfortunately the existing routing algorithms do not take this important factor into account enough [10]. The concept of link usage intensity is used in [10] but it is used to check whether any key links exists before a decision on removing a route from the candidate route table is made. In the network with dynamically changing traffic pattern it is better to pick a route that has a minimum effect for other future connection requests even the distance is longer. Obviously, once the wavelength resource is rapidly exhausted on such links that will lead to network congestion. Similar conditions are caused by not only the static network topology, but also dynamic network traffic. Due to the traffic among the node pairs is not uniformly distributed, the number of connection requests between node pairs may be much more than that between other node pairs. This implies that there may be a significant number of identical connection requests between certain node pairs that need to be satisfied concurrently passing through certain important links denoted as "Key Links". The statistical characteristics for arrival rate of connection request are difficult to define in realistic network, thus lead to the inaccurate predication for link occupation probability. Hence to decrease the network congestion and improve the network resource utilization, the effective strategy is to find out the usage factor of each link and normalizing it with the usage factor of most congested link in the network.At least one of most congested or near-most congested links (generally links with congestion level above 90%) are involved in the capacity exhaustion blocking of the network [11]. In practical scenario, the connection requests from different nodes are correlated sometimes [12]. When designing the routing algorithm, the information of network topology (static) and link's usage frequency (dynamic) as well as the computing complexity should be taken into account

## IV THE PROPOSED SCHEME

When designing the routing algorithm, the information of network topology (static) and link's usage frequency (dynamic) as well as the computing complexity should be taken into account. When the weight function solely based on hop count (HOP) is considered, the effect of frequency of usage of a link on blocking probability and link utilization is ignored. The design of weight function is based on the following observations: When selecting a route, two important factors should be considered: (1) the number of free wavelengths; (2) the hop length of each route. The route with more free wavelengths should be preferred, and at the same time the hop length of that route should not be very long. If there is no wavelength conversion, these two factors are correlated, i.e., a route with shorter length is likely to have more free wavelengths than the routes with longer length. Therefore conventional dynamic RWA algorithms work very well by selecting the route with more free wavelengths if there is no wavelength conversion. However, if the network has the capability of wavelength conversion, the correlation between the number of free wavelengths and the route hop length is weakened, in the sense that a route with longer length is possible to have more free wavelengths than the routes with shorter length. Thus if we always select the route with more free wavelengths, it is possible that such routes have longer route lengths, which can result in a low wavelength utilization and high blocking probability. In the proposed approach apart from minimizing blocking probability the objective of maximizing resource utilization is also taken into account. The routes with minimum hop counts are usually considered because more scope is available for future connection requests (higher number of links are free implies higher degree of freedom).

The proposed approach uses link usage factor to assign weights to each link. It tries to balance the traffic load in the network and considers the Key Links which are usually more likely to cause network congestion and performance deterioration faster. The link usage factor which specifies the dependency of a specific node pair relative to the particular link is calculated which can be summed up with that of other source destination pairs to find out the frequency of usage a link relative to the entire network. The frequency of usage is assigned as the weight for each link (FR). Since the route is selected based on the minimum weight the advantages of minimum hop count are incorporated in this approach. In addition to that the performance degradation due to capacity exhaustion is reduced by assigning more weights to the links with high frequency of usage. Through the concept of Key Links, we can adopt proper measures to reduce traveling through these links that contribute significantly to traffic congestion.

### A System Parameters, Notations

1. The network consists of N nodes and L links.
2. The wavelength channels are labeled as 1 to λ .A route R is a subset of link set {1,2,…L}.
3. The hop length of route is h(R)
4. The physical distance between the nodes on a link is Dij.

### B. Frequency of usage of a link

Capacity Exhaustion Blocking occurs both for networks with wavelength conversion as well as networks without wavelength conversion.. The *frequency of usage* of any link is the number of routes traversing through link in a network. The link with the highest frequency of usage , has the maximum carried traffic and gets congested before any other link in the network and, therefore, is the *most congested link* of the network. The normalization of frequency of usage of any link can be done by dividing the frequency of usage of a link by the frequency of usage of most congested link.

### A. Link Usage Index (LUI)

***LUI*** denote the dependency of specific node pair relative to link L. If certain candidate route passes Link $L_{ij}$ if , j *i* are disparate nodes, then mark

$L_{ij}^{LUI} = 1$

$L_{ij}^{LUI} = 0$ otherwise

. Then $L_{I,J}^{LUI} = \sum L_{ij}^{LUI}$ where (*i j*) and ***(I J)*** represent link and s-d node pair respectively.

Frequency of usage of a link **FR** relates the link's importance relative to whole network. Let

$$FR_{(i,j)} = \sum_{I \neq J} L_{I,J}^{LUI}$$

**(I, J € N)**

**FRmax** is the maximum value of **FR** which denotes the most congested link.

### D. Key Link Concept

This section describes the concept of key links in optical networks. The links with **FR/FRmax** >0.8 influence significantly in traffic congestion and eventually the network performance are designated as key links.

### E. Algorithm Description

1) Find k routes for each s-d node pair according to k shortest algorithm
2) Calculate LI,J LUI = ∑ L i j LUI for each candidate route for a s-d pair
3) Calculate FR for each link.
4) Assign the weight LUI=FR to each link.
5) When connection request arrives for a s-d node pair assign the route which has the least weight
7) After completing route selection, the wavelengths are assigned on this route according to First-Fit algorithm.
8) If the constraints on wavelengths are not satisfied block the request

In honoring the connection request only the shortest route is selected and no additional candidate route is considered

## V Results and Discussion

In our paper we have applied the weight functions to a realistic example of backbone network, namely the NFSNET irregular topology in Fig.1. Permutation routing has been taken for finding out the sample source destination pairs. The number of wavelengths varied are 16,24 and 32.

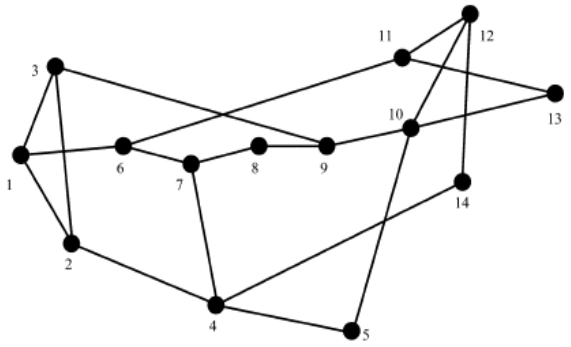
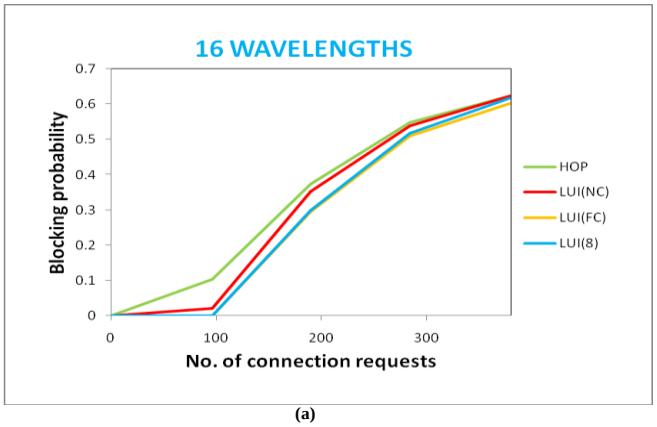



**Fig 1-NSFNET Topology**

The network traffic is generated in terms of connection requests from a source to destination node. The system parameters varied are the number of wavelengths on each link, the number of connection requests .For sparse wavelength conversion the wavelength converters are placed in the nodes that connect the key links with normalized frequency of usage FR/FRmax >0.8.The performance of LUI with wavelength converters placed in 8 nodes that connect top 5 key links is denoted as LUI(8).

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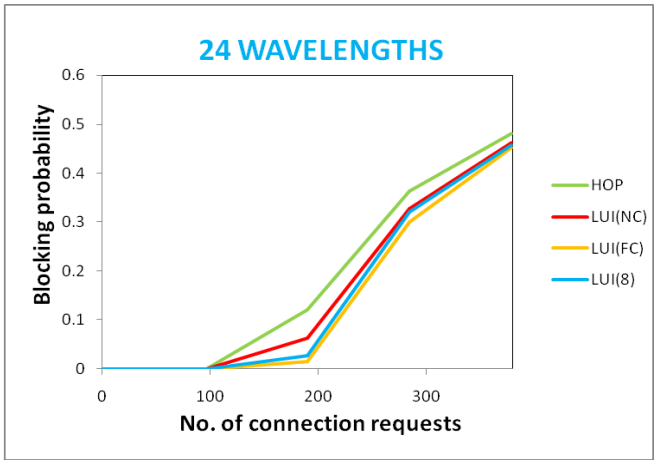


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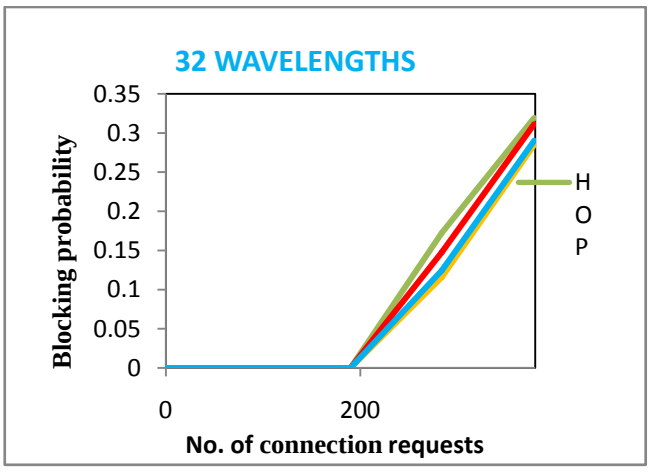
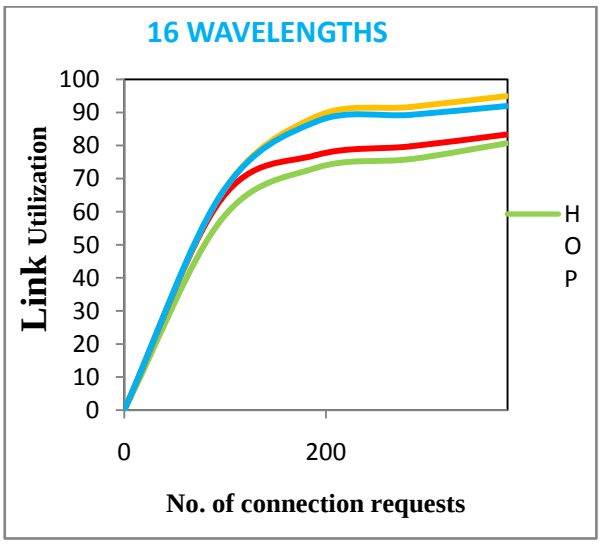



(c)

**Fig. 2. Blocking Probability vs. Connection requests. (a) 16 wavelengths (b) 24 wavelengths (c) 32 wavelengths**

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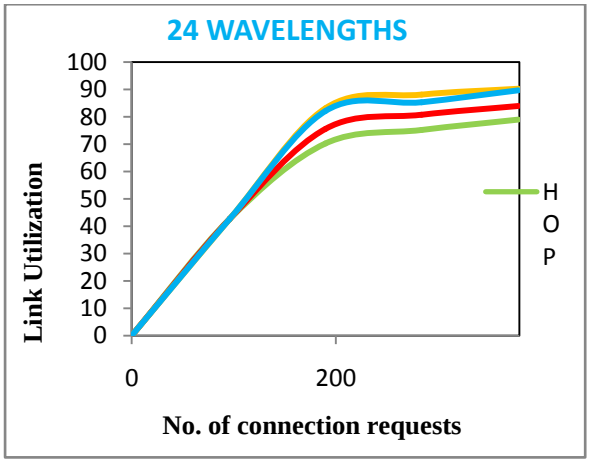


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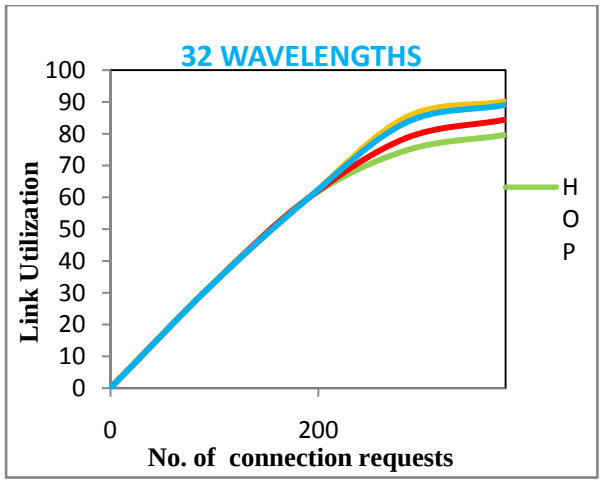


(c)

**Fig. 3. Link Utilization vs. Connection Requests. (a) 16 wavelengths (b) 24 wavelengths ( c) 32 wavelengths**

### *A. Performance Evaluation*

The performance of the dynamic weights based on the proposed approach (LUI) was evaluated and the outputs are compared through simulation with the blocking performance of routing based on hop count(HOP). Simulations were carried out for 16 ,24 and 32 wavelengths per links under no wavelength conversion , full wavelength conversion and sparse wavelength conversion conditions. Fig 2 shows the blocking probability versus connection requests for 16,24 and 32 wavelengths. The results show that there is a remarkable improvement in blocking probability performance for LUI. It compares the performance of full wavelength conversion LUI (FC) ,no wavelength conversion LUI (NC) and hop count HOP with the performance of sparse wavelength conversion where wavelength converters are placed only in 8 nodes(LUI(8)).It can be observed that LUI(8) closely follows the LUI(FC).There is only a marginal difference in performance when wavelength converters are placed only in the 8 nodes which connect the key links over the performance when wavelength converters are placed in all the nodes in the

Network. Thus the concept of key links may be incorporated in wavelength converters placement strategies for performance optimization in WDM networks. Fig 3 shows the link utilization versus connection requests for 16,24 and 32 wavelengths for hop count and LUI under no wavelength conversion , full wavelength conversion and sparse wavelength conversion conditions. In all set of wavelengths the link utilization is better in LUI than the hop count. The results show that the network with full wavelength conversion provides better link utilization compared to network with no wavelength conversion. Overall link utilization decreases as total wavelengths increases, adding extra capacity to the network..

## VI CONCLUSION

This paper studied frequency of usage of a link and their impact on the blocking performance and link utilization in optical networks. Corresponding to varying number of connection requests and set of wavelengths, the blocking probability and link utilization are calculated. An irregular topology network was taken where sessions are assigned light paths for the session duration. The characteristics are investigated for no wavelength conversion, full wavelength conversion and sparse wavelength conversion conditions. Simulation results show that the dynamic weight based on link utilization index yields considerable performance improvement on blocking probability and link utilization. with reduced computational complexity. The proposed approach of placing the wavelength converters in the nodes that connect the key links closely track the performance of full wavelength conversion. Thus improved functioning results by placing the wavelength converters over specific nodes rather than in all the nodes in the network.

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# Lambda Calculus and Functional Programming

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***Abstract*-The lambda calculus can be thought of as an idealized, minimalistic programming language. It is capable of expressing any algorithm, and it is this fact that makes the model of functional programming an important one. This paper is focused on introducing lambda calculus and its application. As an application dikjestra algorithm is implemented using lambda calculus. As program shows algorithm is more understandable using lambda calculus in comparison with other imperative languages.**

## I. INTRODUCTION

Lambda calculus (λ-calculus) is a useful device to make the theories realizable. Lambda calculus, introduced by Alonzo Church and Stephen Cole Kleene in the 1930s is a formal system designed to investigate function definition, function application and recursion in mathematical logic and computer science. It has emerged as a useful tool in the investigation of problems in computability or recursion theory, and forms the basis of a paradigm of computer programming called functional programming.

As lambda calculus is capable of expressing any algorithm the lambda calculus can be thought of as an idealized, minimalistic programming language. Based on these capabilities lambda calculus became an important model of functional programming. Functional programs are stateless and deal exclusively with functions that accept and return data (including other functions), but they produce no side effects in 'state' and thus make no alterations to incoming data. Modern functional languages, building on the lambda calculus, include Erlang, Haskell, Lisp, ML, Scheme and Microsoft has in the past couple years has turned its attention towards functional programming with introduction of .NET based functional programming language called F#.(ref1)

The lambda calculus continues to play an important role in mathematical foundations, through the Curry-Howard correspondence.(ref1)

Church (1936) invented a formal system called the lambda calculus and defined the notion of computable function via this system. Turing (1936, 1937) invented a class of machines (later to be called Turing machines) and defined the notion of computable function via these machines. In 1936 Turing proved that both models are equally strong in the sense that they define the same class of computable functions.

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Basis concept of a Turing machine is the present day Von Neumann computers. Conceptually these are Turing machines with random access registers. Imperative programming languages such as FORTRAN, Pascal etcetera as well as all the assembler languages are based on the way a Turing machine is instructed by a sequence of statements.

In addition functional programming languages, like Miranda, ML etcetera, are based on the lambda calculus. Functional programming is a programming paradigm that treats computation as the evaluation of mathematical functions and avoids state and mutable data. It emphasizes the application of functions, in contrast with the imperative programming style that emphasizes changes in state.

Lambda calculus provides a theoretical framework for describing functions and their evaluation. Though it is a mathematical abstraction rather than a programming language, it forms the basis of almost all functional programming languages today. Modern functional languages can be viewed as embellishments to the lambda calculus. (ref2)

In the next section first we introduce functional programming and after that functional and non-functional programming are compared.

## II. FUNCTIONAL PROGRAMMING

Functional programming languages, especially purely functional ones, have largely been emphasized in academia rather than in commercial software development. However, notable functional programming languages used in industry and commercial applications include Erlang, OCaml, Haskell, Scheme (since 1986) and domain-specific programming languages like R (statistics), Mathematica (symbolic math), J and K (financial analysis), and XSLT (XML).

Many non-functional programming languages such as C, C++ and C# can be made to exhibit functional behaviors using function pointers, the <functional> library and lambda functions respectively.

A functional program consists of an expression E (representing both the algorithm and the input). This expression E is subject to some rewrite rules.

Reduction consists of replacing a part P of E by another expression P' according to the given rewrite rules. In schematic notation

$$E[P] \rightarrow E[P']$$

Provided that P -> P' is according to the rules. This process of reduction will be repeated until the resulting expression has no more parts that can be rewritten. This so called normal form E* of the expression E consists of the output of the given functional program.

Iteration (looping) in functional languages is usually accomplished via recursion. Recursive functions invoke themselves, allowing an operation to be performed over and over. Recursion may require maintaining a stack, but tail recursion can be recognized and optimized by a compiler into the same code used to implement iteration in imperative languages. The Scheme programming language standard requires implementations to recognize and optimize tail recursion.

Functional languages can be categorized by whether they use strict or non-strict evaluation, concepts that refer to how function arguments are processed when an expression is being evaluated.

In brief, strict evaluation always fully evaluates function arguments before invoking the function. Non-strict evaluation is free to do otherwise

To illustrate, consider the following two functions f and g:

f(x) := x^2 + x + 1

g(x, y) := x + y

Under strict evaluation, we would have to evaluate function arguments first, for example:

f(g(1, 4))
= f(1 + 4)
= f(5)
= 5^2 + 5 + 1
= 31

By contrast, non-strict evaluation need not fully evaluate the arguments; in particular it may send the arguments unevaluated to the function, perhaps evaluating them later. For example, one non-strict strategy (call-by-name) might work as follows:

f(g(1, 4))
= g(1, 4)^2 + g(1, 4) + 1
= (1 + 4)^2 + (1 + 4) + 1
= 5^2 + 5 + 1
= 31

A key property of strict evaluation is that when an argument expression fails to terminate, the whole expression fails to terminate. With non-strict evaluation, this need not be the case, since argument expressions need not be evaluated at all.

*Advantages of strict-evaluation can be categorized into two categories as it denoted in below:*

Parameters are usually passed around as (simple) atomic units, rather than as (rich) expressions. (For example, the integer 5 can be passed on a register, whereas the expression 1+4 will require several memory locations). This has a direct implementation on standard hardware.

The order of evaluation is quite clear to the programmer: every argument must be evaluated before the function body is invoked.

*Advantages of non-strict-evaluation can be categorized into three categories as it denoted in below:*

Lambda calculus provides a stronger theoretic foundation for languages that employ non-strict evaluation.

A non-strict evaluator may recognize that a sub-expression does not need to be evaluated. For example, given the definitions

Multiply (0, x) = 0;
Multiply (n, x) = x + multiply (n-1, x);
F (0) = 1;
F (n) = n * f (n-1);

Multiply (0, f (1000000)) a strict evaluator would (strictly speaking) need to take (on the order of) 1,000,000 steps to find the value of f (1000000). A non-strict evaluator may use the definition of multiply first, reducing the whole expression to 0 before even trying to compute f (1000000).

- Non-strict evaluation can use the above to allow "infinite" data structures.

## III. Comparison of Functional and Imperative Programming

Functional programming is very different from imperative programming. The most significant differences stem from the fact that functional programming avoids side effects, which are used in imperative programming to implement state and I/O. Pure functional programming disallows side effects completely. Disallowing side effects provides for referential transparency, which makes it easier to verify, optimize, and parallelize programs, and easier to write automated tools to perform those tasks. This means that pure functions have several useful properties, many of which can be used to optimize the code:

- If the result of a pure expression is not used, it can be removed without affecting other expressions.
- If a pure function is called with parameters that cause no side-effects, the result is constant with respect to that parameter list (sometimes called referential transparency), i.e. if the pure function is again called with the same parameters, the same result will be returned (this can enable caching optimizations).

If there is no data dependency between two pure expressions, then their order can be reversed, or they can be performed in parallel and they cannot interfere with one another (in other terms, the evaluation of any pure expression is thread-safe).

- If the entire language does not allow side-effects, then any evaluation strategy can be used; this gives the compiler freedom to reorder or combine the evaluation of expressions in a program (for example, using lazy evaluation).

While most compilers for imperative programming languages detect pure functions, and perform common-subexpression elimination for pure function calls, they cannot always do this for pre-compiled libraries, which generally do not expose this information, thus preventing optimizations that involve those external functions.

Higher order functions are rarely used in older imperative programming. Where a traditional imperative program might use a loop to traverse a list, a functional style would often use a higher-order function, map, that takes as

arguments a function and a list, applies the function to each element of the list, and returns a list of the results.

## IV. LAMBDA CALCULUS

The **λ**-calculus can be called the smallest universal programming language of the world. The **λ**-calculus consists of a single transformation rule (variable substitution) and a single function definition scheme. It was introduced in the 1930s by Alonzo Church as a way of formalizing the concept of effective computability. The **λ**-calculus is universal in the sense that any computable function can be expressed and evaluated using this formalism. It is thus equivalent to Turing machines. However, the **λ**-calculus emphasizes the use of transformation rules and does not care about the actual machine implementing them. It is an approach more related to software than to hardware.

## V. FORMAL LAMBDA CALCULUS

The central concept in **λ** -calculus is the "expression". A "name", also called a "variable", is an identifier which, for our purposes, can be any of the letters a; b; c,…. An expression is defined recursively as follows:

```
<expression>  :=  <name> | <function> | <application>
  <function>  :=  λ <name>.<expression>
<application> :=  <expression><expression>
```

An expression can be surrounded with parenthesis for clarity, that is, if E is an expression, (E) is the same expression. The only keywords used in the language are **λ** and the dot. In order to avoid cluttering expressions with parenthesis, we adopt the convention that function application associates from the left, that is, the expression
$E_1E_2E_3 \ldots E_n$
is evaluated applying the expressions as follows:
$(\ldots ((E_1E_2)\ E3)\ldots E_n)$
As can be seen from the definition of **λ** expressions given above, a single identifier is a **λ** expression. An example of a function is the following:
**λ** x.x
For instance, the "add-two" function *f* such that $f(x) = x + 2$ would be expressed in lambda calculus as $\lambda\ x.\ x + 2$ (or equivalently as $\lambda\ y.\ y + 2$; the name of the formal parameter is immaterial) and the application of the function $f(3)$ would be written as $(\lambda\ x.\ x + 2)\ 3$. Note that part of what makes this description "informal" is that the expression $x + 2$ (or even the number 2) is not part of lambda calculus; an explanation of how numbers and arithmetic can be represented in lambda calculus is below. Function application is left associative: f x y = (f x) y. Consider the function which takes a function as an argument and applies it to the number 3 as follows: $\lambda\ f.\ f\ 3$. This latter function could be applied to our earlier "add-two" function as follows: $(\lambda\ f.\ f\ 3)\ (\lambda\ x.\ x + 2)$. The three expressions:

$(\lambda\ f.\ f\ 3)\ (\lambda\ x.\ x + 2)$
$(\lambda\ x.\ x + 2)\ 3$
$3 + 2$

are equivalent.
A function of two variables is expressed in lambda calculus as a function of one argument which returns a function of one argument. For instance, the function f(x, y) = x - y would be written as λ x. λ y. x - y. A common convention is to abbreviate curried functions as, in this example, λ x y. x - y. While it is not part of the formal definition of the language,
λ x1 x2 … xn. Expression
Is used as an abbreviation for
λ x1. λ x2. … λ xn. Expression
Not every lambda expression can be reduced to a definite value like the ones above; consider for instance
(λ x. x x) (λ x. x x)
or
(λ x. x x x) (λ x. x x x)
and try to visualize what happens when you start to apply the first function to its argument. (λ x. x x) is also known as the ω combinator; ((λ x. x x) (λ x. x x)) is known as Ω, ((λ x. x x x) (λ x. x x x)) as Ω2, etc.
Lambda calculus expressions may contain free variables, i.e. variables not bound by any λ. For example, the variable y is free in the expression (λ x. y), representing a function which always produces the result y. occasionally, this necessitates the renaming of formal arguments. For example, in the formula below, the letter y is used first as a formal parameter, then as a free variable:
(λ x y. y x) (λ x. y).
To reduce the expression, we rename the first identifier z so that the reduction does not mix up the names:
(λ x z. z x) (λ x. y)
the reduction is then
λ z. z (λ x. y).
If one only formalizes the notion of function application and replaces the use of lambda expressions by the use of combinators, one obtains combinatory logic.

### *A. Definition*

Lambda expressions are composed of

- Variables $v_1, v_2, \ldots v_n$
- The abstraction symbols λ
- Parentheses ( )

The set of lambda expressions, Λ, can be defined recursively:

1. If x is a variable, then x ∈ Λ
2. If x is a variable and M ∈ Λ, then ( λ x . M ) ∈ Λ
3. If M, N ∈ Λ, then ( M N ) ∈ Λ

Instances of 2 are known as abstractions and instances of 3, applications.

### *B. Notation*

To keep the notation of lambda expressions uncluttered, the following conventions are usually applied.
Outermost parentheses are dropped: M N instead of (M N).
Applications are assumed to be left associative: M N P means (M N) P.
The body of an abstraction extends as far right as possible: λ x. M N means (λ x.M N) and not (λ x. M) N

A sequence of abstractions are contracted: λ x λ y λ z. N is abbreviated as λ x y z. N

### C. Free and bound variables

The abstraction operator, λ, is said to bind its variable wherever it occurs in the body of the abstraction. Variables that fall within the scope of a lambda are said to be bound. All other variables are called free. For example in the following expression y is a bound variable and x is free:
λ y . xxy
Also note that a variable binds to its "nearest" lambda. In the following expression one single occurrence of x is bound by the second lambda:
λ x . y (λ x . z x)
The set of *free variables* of a lambda expression, M, is denoted as FV (M) and is defined by recursion on the structure of the terms, as follows:
FV( x ) = {x}, where x is a variable
FV (λ x . M) = FV ( M ) - {x}

FV ( M N ) = FV ( M ) FV ( N )
An expression which contains no free variables is said to be closed. Closed lambda expressions are also known as combinators and are equivalent to terms in combinatory logic.

## VI. Reduction

### A-conversion

Alpha conversion allows bound variable names to be changed. For example, an alpha conversion of λx.x would be λy.y . Frequently in uses of lambda calculus, terms that differ only by alpha conversion are considered to be equivalent.
The precise rules for alpha conversion are not completely trivial. First, when alpha-converting abstractions, the only variable occurrences that are renamed are those that are bound to the same abstraction. For example, an alpha conversion of λx.λx.x could result in λy.λx.x , but it could *not* result in λy.λx.y . The latter has a different meaning from the original.
Second, alpha conversion is not possible if it would result in a variable getting captured by a different abstraction. For example, if we replace $x$ with $y$ in λx.λy.x, we get λy.λy.y, which is not at all the same.

### A. Substitution

Substitution, written E[V := E'], corresponds to the replacement of a variable V by expression E' every place it is free within E. The precise definition must be careful in order to avoid accidental variable capture. For example, it is not correct for (λ x.y)[y := x] to result in (λ x.x), because the substituted x was supposed to be free but ended up being bound. The correct substitution in this case is (λ z.x), up-to α-equivalence.
Substitution on terms of the λ-calculus is defined by recursion on the structure of terms, as follows.
x[x := N] ≡ N
y[x := N] ≡ y, if x ≠ y
$(M_1\ M_2)[x := N] \equiv (M_1[x := N])\ (M_2[x := N])$
(λ y. M)[x := N] ≡ λ y. (M[x := N]), if x ≠ y and y∉fv(N)
Notice that substitution is defined uniquely up-to α-equivalence.
*β-reduction*
Beta reduction expresses the idea of function application. The beta reduction of ((λ V. E) E') is simply E[V := E'] .

### H-conversion

Eta conversion expresses the idea of extensionality, which in this context is that two functions are the same if and only if they give the same result for all arguments. Eta-conversion converts between λ x. f x and f whenever x does not appear free in f.
This conversion is not always appropriate when lambda expressions are interpreted as programs. Evaluation of λ x. f x can terminate even when evaluation of *f* does not.

## VII. Arithmetic in Lambda Calculus

There are several possible ways to define the natural numbers in lambda calculus, but by far the most common are the Church numerals, which can be defined as follows:
0:= λ f x. x
1:= λ f x. f x
2:= λ f x. f (f x)
3:= λ f x. f (f (f x))
And so on.
A Church numeral is a higher-order function—it takes a single-argument function f, and returns another single-argument function. The Church numeral n is a function that takes a function f as argument and returns the n-th composition of f, i.e. the function f composed with itself n times. This is denoted f(n) and is in fact the n-th power of f (considered as an operator); f(0) is defined to be the identity function. Such repeated compositions (of a single function f) obey the laws of exponents, which is why these numerals can be used for arithmetic. Note that 1 returns f itself, i.e. it is essentially the identity function, and 0 returns the identity function. (Also note that in Church's original lambda calculus, the formal parameter of a lambda expression was required to occur at least once in the function body, which made the above definition of 0 impossible.)
We can define a successor function, which takes a number $n$ and returns $n + 1$ by adding an additional application of $f$:
SUCC: = λ n f x. f (n f x)
Because the $m$-th composition of $f$ composed with the $n$-th composition of $f$ gives the $m+n$-th composition of $f$, addition can be defined as follows:
PLUS: = λ m n f x. n f (m f x)
PLUS can be thought of as a function taking two natural numbers as arguments and returning a natural number; it can be verified that
PLUS 2 3 and 5

Are equivalent lambda expressions. Since adding m to a number, n can be accomplished by adding 1 m times, an equivalent definition is:
PLUS: = λ n m. m SUCC n
Similarly, multiplication can be defined as
MULT: = λ m n f . m (n f)
Alternatively
MULT: = λ m n. m (PLUS n) 0,
Since multiplying m and n is the same as repeating the "add n" function m times and then applying it to zero. The predecessor function defined by PRED n = n - 1 for a positive integer n and PRED 0 = 0 is considerably more difficult. The formula
`PRED: = λ n f x. n (λ g h. h (g f)) (λ u. x) (λ u. u)`
Can be validated by showing inductively that if `T` denotes `(λ g h. h (g f))`, then $T^{(n)}(\lambda u.\ x) = (\lambda h.\ h(f^{(n-1)}(x))\ )$ for n > 0. Two other definitions of PRED are given below, one using conditionals and the other using pairs. With the predecessor function, subtraction is straightforward. Defining
`SUB: = λ m n. n PRED m`,
`SUB m n` yields $m - n$ when $m > n$ and `0` otherwise.

## VIII. Logic and Predicates

By convention, the following two definitions (known as Church booleans) are used for the boolean values `TRUE` and `FALSE`:
`TRUE: = λ x y. x`
`FALSE: = λ x y. y`
(Note that `FALSE` is equivalent to the Church numeral zero defined above)
Then, with these two λ-terms, we can define some logic operators (these are just possible formulations; other expressions are equally correct):
`AND: = λ p q. p q p`
`OR: = λ p q. p p q`
`NOT: = λ p. λ a b. p b a`
`IFTHENELSE: = λ p a b. p a b`
We are now able to compute some logic functions, for example:
`AND TRUE FALSE`
≡ `(λ p q. p q p) TRUE FALSE` $\rightarrow_\beta$ `TRUE FALSE TRUE`
≡ `(λ x y. x) FALSE TRUE` $\rightarrow_\beta$ `FALSE`
and we see that `AND TRUE FALSE` is equivalent to `FALSE`.
A *predicate* is a function which returns a boolean value. The most fundamental predicate is `ISZERO` which returns `TRUE` if its argument is the Church numeral `0`, and `FALSE` if its argument is any other Church numeral:
`ISZERO: = λ n. n (λ x. FALSE) TRUE`
The following predicate tests whether the first argument is less-than-or-equal-to the second:
`LEQ:= λ m n. ISZERO (SUB m n)`,
and since $m = n$ iff `LEQ m n` and `LEQ n m`, it is straightforward to build a predicate for numerical equality.

The availability of predicates and the above definition of `TRUE` and `FALSE` make it convenient to write "if-then-else" expressions in lambda calculus. For example, the predecessor function can be defined as' '
`PRED: = λ n. n (λ g k. ISZERO (g 1) k (PLUS (g k) 1)) (λ v. 0) 0`
Which can be verified by showing inductively that `n (λ g k. ISZERO (g 1) k (PLUS (g k) 1)) (λ v. 0)` is the "add $n$ - 1" function for $n > 0$.

## IX. Pairs

A pair (2-tuple) can be defined in terms of `TRUE` and `FALSE`, by using the Church encoding for pairs. For example, `PAIR` encapsulates the pair $(x,y)$, `FIRST` returns the first element of the pair, and `SECOND` returns the second.
PAIR:= λ x y f. f x y
FIRST: = λ p. p TRUE
SECOND: = λ p. p FALSE
NIL: = λ x. TRUE
NULL: = λp. p (λx y.FALSE)
A linked list can be defined as either NIL for the empty list, or the `PAIR` of an element and a smaller list. The predicate `NULL` tests for the value `NIL`.
As an example of the use of pairs, the shift-and-increment function that maps $(m, n)$ to $(n, n+1)$ can be defined as
`Φ := λ x. PAIR (SECOND x) (SUCC (SECOND x))`
which allows us to give perhaps the most transparent version of the predecessor function:
`PRED := λ n. FIRST (n Φ (PAIR 0 0))`

## X. Recursion

Recursion is the definition of a function using the function itself; on the face of it, lambda calculus does not allow this. However, this impression is misleading. Consider for instance the factorial function $f(n)$ recursively defined by
$f(n) = 1$, if $n = 0$; and $n \cdot f(n-1)$, if $n>0$.
In lambda calculus, one cannot define a function which includes itself. To get around this, one may start by defining a function, here called $g$, which takes a function $f$ as an argument and returns another function that takes $n$ as an argument:
`g := λ f n. (1, if n = 0; and n·f(n-1), if n>0).`
The function that $g$ returns is either the constant `1`, or $n$ times the application of the function $f$ to $n-1$. Using the `ISZERO` predicate, and boolean and algebraic definitions described above, the function $g$ can be defined in lambda calculus.
However, $g$ by itself is still not recursive; in order to use $g$ to create the recursive factorial function, the function passed to $g$ as $f$ must have specific properties. Namely, the function passed as $f$ must expand to the function $g$ called with one argument -- and that argument must be the function that was passed as $f$ again!

In other words, `f` must expand to `g(f)`. This call to `g` will then expand to the above factorial function and calculate down to another level of recursion. In that expansion the function `f` will appear again, and will again expand to `g(f)` and continue the recursion. This kind of function, where `f = g(f)`, is called a *fixed-point* of `g`, and it turns out that it can be implemented in the lambda calculus using what is known as the *paradoxical operator* or *fixed-point operator* and is represented as `Y` -- the Y combinator:

`Y = λ g. (λ x. g (x x)) (λ x. g (x x))`

In the lambda calculus, `Y g` is a fixed-point of `g`, as it expands to `g (Y g)`. Now, to complete our recursive call to the factorial function, we would simply call `g (Y g) n`, where *n* is the number we are calculating the factorial of.

Given *n* = 5, for example, this expands to:
(λ n.(1, if n = 0; and n·((Y g)(n-1)), if n>0)) 5
1, if 5 = 0; and 5·(g(Y g)(5-1)), if 5>0
5·(g(Y g) 4)
5·(λ n. (1, if n = 0; and n·((Y g)(n-1)), if n>0) 4)
5·(1, if 4 = 0; and 4·(g(Y g)(4-1)), if 4>0)
5·(4·(g(Y g) 3))
5·(4·(λ n. (1, if n = 0; and n·((Y g)(n-1)), if n>0) 3))
5·(4·(1, if 3 = 0; and 3·(g(Y g)(3-1)), if 3>0))
5·(4·(3·(g(Y g) 2)))

And so on, evaluating the structure of the algorithm recursively. Every recursively defined function can be seen as a fixed point of some other suitable function, and therefore, using `Y`, every recursively defined function can be expressed as a lambda expression. In particular, we can now clearly define the subtraction, multiplication and comparison predicate of natural numbers recursively.

## XI. Implementation and Application

The strength of the lambda-calculus is that it is easily used as "glue" on top of a richer world of primitives. Its advantages as glue are that it has a natural correspondence with the way that people program, and natural compilation techniques yield high-performance code.

There are software engineering advantages to a language glued together with lambda-calculus. Lambda expressions can be understood locally - their dependence on their environment is entirely through their free variables. Lambda expressions tend to have fewer free variables and more bound variables than comparable imperative code, since they do not rely as heavily on assignment to express the computation. An imperative program proceeds by altering some globally-accessible store of values. By contrast, a functional program proceeds by function application and the return of values. This eliminates large classes of errors associated with maintaining a global store of values.

Based on these advantages we are interested in implementing some algorithm by lambda calculus as a programming language. In this regards, djikstra as an algorithm to find the shortest path between two nodes in a graph is implemented. Dijkstra's algorithm, conceived by Dutch computer scientist Edsger Dijkstra in 1959, is a graph search algorithm that solves the single-source shortest path problem for a graph with non negative edge path costs, outputting a shortest path tree. This algorithm is often used in routing.

For a given source vertex (node) in the graph, the algorithm finds the path with lowest cost (i.e. the shortest path) between that vertex and every other vertex. It can also be used for finding costs of shortest paths from a single vertex to a single destination vertex by stopping the algorithm once the shortest path to the destination vertex has been determined. For example, if the vertices of the graph represent cities and edge path costs represent driving distances between pairs of cities connected by a direct road, Dijkstra's algorithm can be used to find the shortest route between one city and all other cities. As a result, the shortest path first is widely used in network routing protocols.

Let's call the node we are starting with an initial node. Let a distance of a node X be the distance from the initial node to it. Our algorithm will assign some initial distance values and will try to improve them step-by-step.

1. Assign every node a distance value. Set it to zero for our initial node and to infinity for all other nodes.
2. Mark all nodes as unvisited. Set initial node as current.
3. For current node, consider all its unvisited neighbors and calculate their distance (from the initial node) in case they are reached through the current node. For example, if current node (A) has distance of 6, and an edge connecting it with another node (B) is 2, the distance to B through A will be 6+2=8. If this distance is less than the previously recorded distance (infinity in the beginning, zero for the initial node), overwrite the distance.
4. When we are done visiting all neighbors of the current node, mark it as visited. A visited node will not be checked ever again, its distance recorded now is final and minimal.
5. Set the nearest unvisited neighbor of the current node as the next "current node" and continue from step 3.
6. When all nodes are visited, algorithm ends.

The program using lambda calculus languages became as illustrated in below:

λ n. n (λ x. λ x y. y) λ x y. x
Weight Node. λ n. n (λ x. λ x y. y) λ x y. x Weight Node
λ n f x. f (n f x)
λ m n. λ n. n (λ x. λ x y. y) λ x y. x (λ m n. n λ n. n (λ g k. λ n. n (λ x. λ x y. y)
λ x y. x (g λ f x. f x ) k (λ m n f x. n f (m f x) (g k) λ f x. f x ) )
(λ v. λ f x. x ) λ f x. x m n) Weight Node. m n. λ n. n (λ x. λ x y. y) λ x y. x (λ m n. n λ n. n (λ g k. λ n. n (λ x. λ x y. y )
λ x y. x (g λ f x. f x ) k (λ m n f x. n f (m f x) (g k) λ f x. f x ) ) (λ v. λ f x. x ) λ f x. x m n) Weight Node y f. f λ m n. λ n. n (λ x. λ x y. y)
λ x y. x (λ m n. n λ n. n (λ g k. λ n. n (λ x. λ x y. y ) λ x y. x (g 1) k (λ m n f x. n f (m f x) (g k) λ f x. f x ) ) (λ v. λ f x. x ) λ f x. x

m n) Weight Node. m n. λ n. n (λ x. λ x y. y) λ x y. x (λ m n. n λ n. n (λ g k. λ n. n (λ x. λ x y. y )
λ x y. x (g 1) k (λ m n f x. n f (m f x) (g k) λ f x. f x ) ) (λ v. λ f x. x ) λ f x. x m n) Weight Node y

In comparison with the other programming languages, as an example we wrote some of them in below, Lambda expressions tend to have fewer free variables and more bound variables than comparable imperative code. In addition it is easier to understand the algorithm in lambda-based program because our understandings are not limited to the variable definition.

## XII. Python Implementation

```
Import heapq
From collections import defaultdict

class Edge(object):
  def __init__(self, u, v, weight):
    self.start, self.end, self.weight = u, v, weight

  # For heapq.
  def __cmp__(self, other): return cmp(self.weight, other.weight)

class Graph(object):
  def __init__(self):
    # The adjacency list.
    self.adj = defaultdict(list)

  def add_e(self, u, v, weight = 0):
    self.adj[u].append (Edge (u, v, weight))

  def s_path(self, src):
    """
    Returns the distance to every vertex from the source and the
    array representing, at index i, the node visited before
    visiting node i. This is in the form (dist, previous).
    """
    dist, visited, previous, queue = {src: 0}, {}, {}, []
    heapq.heappush(queue, src)
    while len(queue) > 0:
      current = heapq.heappop(queue)
      if current in visited:
        Continue
      visited[current] = True

      for edge in self.adj[current]:
        relaxed = dist[current] + edge.weight
        v = edge.end
        if v not in dist or relaxed < dist[v]:
          previous[v], dist[v] = current, relaxed
          heapq.heappush(queue, v)
    return dist, previous

g = Graph()
g.add_e(1,2,4)
g.add_e(1,4,1)
g.add_e(2,1,74)
g.add_e(2,3,2)
g.add_e(2,5,12)
g.add_e(3,2,12)
g.add_e(3,10,12)
g.add_e(3,6,74)
g.add_e(4,7,22)
g.add_e(4,5,32)
g.add_e(5,8,33)
g.add_e(5,4,66)
g.add_e(5,6,76)
g.add_e(6,10,21)
g.add_e(6,9,11)
g.add_e(7,3,12)
g.add_e(7,8,10)
g.add_e(8,7,2)
g.add_e(8,9,72)
g.add_e(9,10,7)
g.add_e(9,6,31)
g.add_e(9,8,18)
g.add_e(10,6,8)

# Find a shortest path from vertex 'a' (1) to 'j' (10).
Dist, prev = g.s_path(1)
# Trace the path back using the prev array.
Path, current, end = [], 10, 10
While current in prev:
  path.insert(0, prev[current])
  current = prev[current]

print path
print dist[end]
```

as it is clear, the program written first is much easier to develop because the developer is not supposed to know syntaxes. Although lambda calculus is easy, it is not a user friendly language which should be like human's language.

## XIII. CONCLUSION

The strength of the lambda-calculus is that it is easy to use and in order to implement, you are not supposed to learn a huge amount of syntaxes. In comparison to other, although lambda calculus is easy, it is not a user friendly language which should be like human's language.

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**15. Use of direct quotes:** When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

**16. Use proper verb tense:** Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

**17. Never use online paper:** If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. **Pick a good study spot:** To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

**19. Know what you know:** Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

**20. Use good quality grammar:** Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

**21. Arrangement of information:** Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

**22. Never start in last minute:** Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

**23. Multitasking in research is not good:** Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

**24. Never copy others' work:** Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

**25. Take proper rest and food:** No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

**26. Go for seminars:** Attend seminars if the topic is relevant to your research area. Utilize all your resources.

**27. Refresh your mind after intervals:** Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also

improve your memory.

**28. Make colleagues:** Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. **Think technically:** Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

**30. Think and then print:** When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

**31. Adding unnecessary information:** Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

**32. Never oversimplify everything:** To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

**33. Report concluded results:** Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

**34. After conclusion:** Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

## Informal Guidelines of Research Paper Writing

**Key points to remember:**

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

**Final Points:**

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

**General style:**

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

*To make a paper clear*

· Adhere to recommended page limits

*Mistakes to evade*

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

*In every sections of your document*

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

**Title Page:**

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

**Abstract:**

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.



Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

**Introduction:**

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.
- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

**Procedures (Methods and Materials):**

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

**Results:**

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.

You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or

additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

**Discussion:**

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described.
Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work

- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

## Administration Rules Listed Before Submitting Your Research Paper to Global Journals

*Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals:*

**Segment Draft and Final Research Paper:** You have to strictly follow the template of research paper. If it is not done your paper may get rejected.

- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.
- Do not give permission to anyone else to "PROOFREAD" your manuscript.

**Written Material:** You may discuss with your guides and key sources.

- Do not copy or imitate anyone else paper. (Various Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

## Criterion for Grading a Research Paper *(Compilation)* by Global Journals

**Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.**

| Topics | Grades | | |
|---|---|---|---|
| | **A-B** | **C-D** | **E-F** |
| ***Abstract*** | Clear and concise with appropriate content, Correct format. 200 words or below | Unclear summary and no specific data, Incorrect form<br><br>Above 200 words | No specific data with ambiguous information<br><br>Above 250 words |
| ***Introduction*** | Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited | Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter | Out of place depth and content, hazy format |
| ***Methods and Procedures*** | Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads | Difficult to comprehend with embarrassed text, too much explanation but completed | Incorrect and unorganized structure with hazy meaning |
| ***Result*** | Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake | Complete and embarrassed text, difficult to comprehend | Irregular format with wrong facts and figures |
| ***Discussion*** | Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited | Wordy, unclear conclusion, spurious | Conclusion is not cited, unorganized, difficult to comprehend |
| ***References*** | Complete and correct format, well organized | Beside the point, Incomplete | Wrong format and structuring |

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