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"EXPERIMENTAL ANALYSIS OF EMISSION PERFORMANCE CHARACTERISTICS ON DIESEL AND DIESEL-BIODIESEL BLENDS WITH EXHAUST GAS RECIRCULATION"

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Abstract - *The method of experimental work in the first stage, stationary single cylinder four stroke constant speed direct injection diesel engine is operated with different blends of diesel & Jatropha biodiesel at natural aspirated mode. The different blends like B10, B20, Jatropha biodiesel with diesel are tested in a conventional diesel engine, in order to find the best one in terms of performance and emission characteristics. In the second stage, the experiments are carried out on a single cylinder constant speed direct injection diesel engine under exhaust gas recirculation (EGR) mode with the best blend (B10 and B20) of Jatropha biodiesel at different exhaust gas recirculation (EGR) rates (10 and 20 %).*

Key Words: CO Emissions, Exhaust Gas recirculation, HC emissions, NOx Emissions, Jatropha Oil. Biodiesel

1. INTRODUCTION

In 1911 Dr. Rudolf Diesel says, **"The diesel will be sustained with vegetable oils and would encourage altogether inside the advancement of the farming of the nations which can utilize it"** He incontestable the work of a one of a kind of vegetable oils, and a great deal of being attempted since.

1.1. ENERGY CONVERSION

Internal combustion engines are being extensively used for transportation, farming and in power generation. the employment of petroleum-based mostly fuels within the internal combustion engine has crystal rectifier to many issues like pollution, environmental degradation endangering the health of people at large and different biological species, economic and political issues throughout the planet. Therefore, major efforts are towards reducing emissions from combustion engines and therefore the two approaches are

[1] Engine design changes
[2] Usage of biofuels and alternate fuels in the place of petroleum based fuels.

Though biofuels are well-known to public they're however to realize such attention towards total replacement of fossil fuels. Still, internal combustion engines square measure being propelled by the oil derived merchandise because the engines are developed for a particular fuel solely. Today's engine technology is far a lot of advanced and adopting biofuels for the current engines while not ever-changing the technology has become a challenging task.

1.2. HISTORICAL BACKGROUND OF BIODIESEL

Dr. Rudolf diesel, who fictitious the first internal-combustion engine in 1895, used only bio fuel in his engine. His visionary statement was "The use of vegetable oils for engine fuel might appear insignificant recently, but such oils may become in course of it slow, as very important as oil and pitch product of this time". The above prediction is becoming true recently as further and extra biodiesel is being utilized all over within the world.

1.3 ECONOMIC FEASIBILITY OF BIODIESEL

The Biofuels market has been witnessing endless growth and developments across the planet over the past few years. Governments across the planet are feeding large cash Associate in Nursing resources into the event of this sector in an attempt to scale back their dependency on oil. The essential oil costs and production levels have more enlightened the necessity for continuous development during this sector. During 2001-2006 alone, the worldwide annual production of biodiesel and alcohol grew by forty third and twenty third, severally. The most important economic issue to contemplate for input prices of biodiesel production is that the feedstock (price of seed, seed assortment and oil extraction, transport of seed and oil), that is regarding 75–80% of the entire operative cost.

1.4. INTERNATIONAL SCENARIO OF BIODIESEL

Global production of biofuels has been growing chop-chop. several countries around the world area unit embarking on formidable biofuel policies through renewable fuel standards and economic incentives. As a result, each world biofuel demand and supply is predicted to grow terribly chop-chop over the subsequent twenty years, provided policymakers maintain their policy goals. Whereas the motivation for this enlargement is complex, the foremost vital explanation is to boost national energy security.

1.7. ENGINE EMISSIONS AND THEIR CONTROL

It has become a difficult task for the engine makers to develop engines and fuels that turn out lower emissions and while not a major impact on the environment. At present, engine after-treatment and pre-treatment technologies are widely adopted to attain low emissions. Once the treatment technique in the main uses thermal or chemical action converters and particulate traps. The pre-treatment strategies embody exhaust gas recirculation (EGR), usage of fuel additives and mixing of biofuels to diesel. Several methodologies are tried by the researchers to use biofuels on with pre and post-treatment strategies to minimize harmful pollutant emissions.

2. THE SCOPE FOR PRESENT RESEARCH WORK

The present study envisages highlighting the need of shifting from petroleum based fuels to biofuels for the present C.I engines. The study supports the view by searching for new feed stocks as an alternate to petroleum diesel, and various methodologies of usage of biofuels in the diesel engine promising low emissions and improved performance. The results of the tests would enhance the understanding of engines working under similar conditions. Jatropha oil and other non edible oils are being identified as feed stocks to convert them into biodiesel by using transesterification and pyrolysis processes. The biodiesel (jatropha oil and other non edible oils) have been prepared an optimized for best efficiency. The methods like natural aspiration and exhaust gas recirculation (EGR) have been adopted to understand the performance and emission nature of the selected fuels with the C.I engine. The performance, combustion parameters, emissions of carbon monoxide (CO), hydrocarbons (HC), smoke and nitrous oxides (NOx) were measured at all test conditions.

3. METHODOLOGY

Biodiesel has become more attractive recently because of its environmental benefits and the act that it is made from renewable resources. The cost of biodiesel, however, is the main hurdle for commercialization of the product. Fuels like alcohol, biodiesel, liquid fuel from plastics and tyres are some of the alternative fuels for the I.C engines.

The experimental work is considered in the background of modest information available in the literature for the constant speed engines. A possible thorough investigation has been launched to understand the engine performance with biofuels in different modes of operation. For this a commercially available single cylinder Kirloskar diesel engine was chosen. The engine operations have been found to be exigent, operating simultaneously in natural aspirated, and EGR modes. Some minor problems, experienced during the engine tests were resolved subsequently through proper maintenance and precautionary measures.

3.1 BIODIESEL PEODUCTION

Here in this from starting the raw materials used for biodiesel production is discussed and after it with the each step with which the whole production process was undergone. The biodiesel properties are also discussed in this section. The crude oil was used for the preparation of biodiesel. The first stage included an acid catalyzed esterification reaction and in second the base catalyzed transesterification reaction was carried out.

3.1.1. ACID ESTERIFICATION

3.1.2. ALKALINE TRANSESTERIFICATION

3.2. DESCRIPTION OF THE ENGINE

Experiments were conducted on a single cylinder constant speed diesel engine with a fixed compression ratio of 16.5 and with a constant speed of 1500 rpm under different modes as explained earlier. The choice of this kind of engine is made because of the consideration that these engines are the leading prime movers for agricultural, construction, industrial, and power generation applications in India. The test results would be useful for the engines working under similar operating conditions, engines fuelled with similar biofuels, and for imminent research work on development of biofuels.

3.3. INSTRUMENTATION OF THE ENGINE TEST SETUP

3.3.1. OSCILLOSCOPE FOR MONITORING IN-CYLINDER PRESSURE

An oscilloscope has been used to track the in-cylinder pressure pulses. The input to the oscilloscope is the charge amplifier where the signals from a piezo resistive type pressure sensor are amplified and the indicated pressure developed during one thermodynamic cycle has been monitored at different operating conditions of the engine. The pressure sensor is a diaphragm formed on a silicon substrate, which bends with applied pressure and a deformation occurs in the crystal lattice of the diaphragm because of that bending. This deformation causes a change in the band structure of the piezo resistors that are placed on the diaphragm, leading to a change in the resistivity of the material. The changes in the resistivity can be amplified by a charge amplifier.

3.3.2. DC SHUNT DYNAMOMETER WITH SPEED MEASUREMENT

A universal dynamometer equipped with a DC shunt generator as an absorbing unit used to measure the engine torque along with an additional arrangement for measuring speed in RPM. The dynamometer unit also has an arrangement for measuring frictional power of the engine.

3.3.3. FLOW MEASUREMENT

Rotameters have been used for flow measurement of inlet air charge and exhaust gas (EGR). Rotameter is a particular kind of flow meter, based on the variable area principle; they provide a simple, precise and economical means of measuring flow rates in fluid systems.

3.3.4. EMISSION MEASUREMENT

The emissions and exhaust temperature was measured in the exhaust manifold. The temperatures have been measured using k type (Chromel-Alumel) thermocouple. Adequate provision was made to condition the flue gas sample prior to the measurements and the flue gas composition was analyzed using a multi component analyzer which is based on infrared and chemical cell techniques. The substances measured were nitric oxide (NO), carbon monoxide (CO), carbon dioxide (CO2), hydrocarbons (HC), unused oxygen (O2) and smoke emissions on the intermittent basis.

3.3.5. FIVE GAS ANALYSER

AVL build 5-Gas instrument is employed to live emissions of CO, HC, CO2, O2, and NOx. It measures CO, HC, and carbonic acid gas victimization infrared mensuration and O2 and Nox victimization chemistry mensuration technique. The AVL DiGas 4000 5 gas instrument was accustomed live Nox, CO2, UBHC, CO and O2 of CI engine exhaust gas in a very mensuration chamber. Associate infrared exhaust gas instrument was used for the mensuration of HC/CO/CO2 within the exhaust. For mensuration NOx/O2, associate chemistry instrument was used. The AVL DiGas 4000 gas instrument used for exhaust gases as shown in figure 3.4

Figure 3.4: AVL DiGas 4000 Five Gas Analyzer

3.4. ENGINE SET-UP

This experimental research was carried out in a single cylinder, 4 times, manufactured by Kirloskar (model TV1), DI diesel engine. It was connected to the control panel unit, which consists of a rotameter, a water temperature indicator, a load switch, a speed indicator and a fuel flow transmitter, etc. The thermal efficiency of the brakes (BTE), the exhaust gas temperature (EGT), the cylinder pressure and the rate of heat release were determined by the engine performance analysis software (EnginesoftLV).

Figure 3.5: CI Engine used for Performance Analysis

Figure 3.6: Photographic view of experimental setup showing EGR path

3.5. EXHAUST GAS RECIRCULATION (EGR) SET UP

Engine setup has been modified to work with exhaust gas recirculation. The EGR system designed as cooled low pressure system, and the cooling of exhaust gas was carried out by a water cooled heat exchanger. The flow rate of water through the heat exchanger was adjusted to get the desired inlet charge temperature. The EGR rate was calculated based on the equation (4.1) and EGR flow rate was measured by a rotameter. The EGR rates maintained were, 10%, and 20%. Observable engine speed fluctuations were noticed with higher EGR rates (greater than 10%) and EGR rate more than 20% resulted in shutting down of the engine process due to increased dilution of the incoming air charge with exhaust gases.

$$\%\ EGR = \frac{\text{Volume flow rate of recirculated exhaust gas}}{\text{Volume flow rate of charge into the cylinder}} \times 100$$

Obtaining a desired EGR rate has been accomplished by mixing of the inlet air and exhaust gas of known flow rates using the equation (3.1). To achieve fruitful operation of EGR a venturi tube has been designed and coupled with engine setup to mix the fresh air with exhaust gas before the process of combustion.

3.5.1. PRINCIPLE OF VENTURI

A venturi is a system for speeding the flow of the fluid, by constricting it in a cone shape tube. When the fluid is allowed to pass through constriction, the velocity increases with a decrease in pressure creating a partial vacuum and when the fluid leaves the constriction its pressure increases back to the ambient. A venturi can also be used to inject a fluid into another fluid for effective mixing. In the present case the venturi system has been designed to mix effectively the fresh air and exhaust gas to result in different EGR rates.

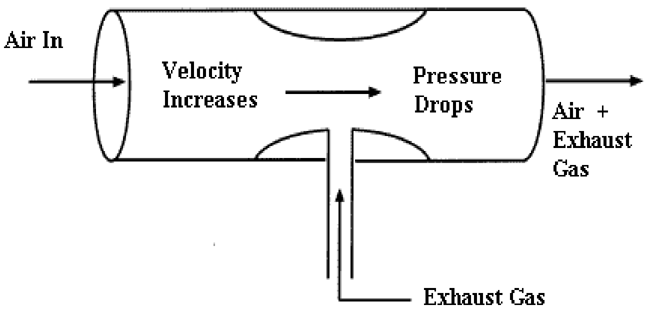

Figure 3.7: Principle of a venturi

The principle of venture tube is shown in the Fig. 4.7, and the schematic of venturi tube designed for the present EGR system is shown in Fig. 4.8. With the dimensions of venturi tube given in centimeters.

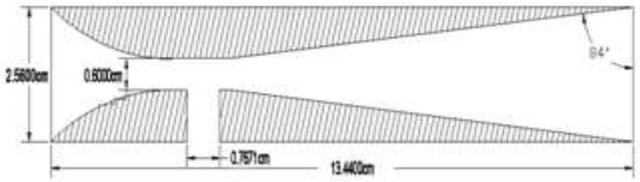

Figure 3.8: Design of venture tube for mixing of exhaust gas and fresh air for EGR operation

3.6. DETAILS OF EXPERIMENTAL WORK

3.6.1. PREPARATION OF BIODIESEL BLENDS

For this experimental investigation four blends i.e. B10 and B20 are prepared and tested for different characterization. The blends are shown follows.

 B10 – 10% Biodiesel and 90% Diesel
 B20 – 20% Biodiesel and 80% Diesel

3.6.2. DETERMINATION OF BIODIESEL PROPERTIES

Several properties of biodiesel and its blends with diesel have been determined in this experimental investigation. These are

Table 3.1: Different Properties of Different Biodiesel

Property	Unit	Diesel	Jatropha biodiesel	B10	B20
Density	g/cm^3	0.820	0.880	0.877	0.866
Kinematic Viscosity	mm^2/s	2.98	4.328	4.320	4.230
Acid value	mgKOH /gm	0.35	0.32	88	89
Cloud point	°C	-16			
Flash point	°C	144	140		
Cetane number		49.0	57	55	51
Calorific value	Kcal/KG	42850	40000	42000	41200
Moisture	%	0.02	0.03	0.023	0.02
Ash content	wt %	0.02	0.02	0.017	0.019

3.7. EXPERIMENTAL PROCEDURE FOR PERFORMANCE ANALYSIS

This experimental investigation was done with diesel fuel as well as 2 different blends B10 and B20 The procedure is discussed below:

- At first the primary fuel tank was filled with diesel fuel.
- The desired compression ratio was adjusted i.e. 17.5:1 by lock nut of adjuster.
- After starting the water pump, the cooling water ratameter flow rate and calorimeter rotameter flow rate was adjusted at 300 LPH and 70 LPH respectively.
- Ensured that the position of fuel cock at "Tank".
- The engine was started by hand cranking and ran at no load condition at least 4-5 min.
- Now opened the "EnginesoftLV" software on monitor for engine performance analysis.
- Increase the load 0.5 kg by adjusted DLU knob (ensure that the increased load reading same as computer) and change the position of fuel cock from "Tank" to "Measuring". After clicking on "Log on", the data such as water flow to calorimeter, engine and cooling water jacket was entered into input display. At no load condition, the data was recorded for the engine and then the fuel position was changed from "Measuring" to "Tank".

4. RESULT ANALYSIS

The experiment results related smoke, NOx discharge, execution qualities, and warmth discharge rate of an IDI car diesel motor for biodiesel was examined and looked at. The primary outcomes got from these assessments are introduced in the accompanying passage. Some data of biodiesel and diesel is given. Likewise, plausible impacts of biodiesel mixing process, smoke obscurity, and NOx discharge are introduced in individually. After the effects on the engine performance characteristics, in-cylinder pressure and temperature and heat release rate and Brake thermal efficiency will be given in respectively and obtained results discussed comprehensively.

4.1 EMISSION

4.1.1 HYDRO CARBON VS BRAKE POWER

HC emissions from the test fuels B10 and B20 with 10 and 20 % EGR at even with dissimilar engine brake power. There are quantities of motives for the HC emission through combustion. Fuel trapping in the split volumes of the combustion chamber is one of the main motives of HC emission. It can be seen from the fig.4.1,

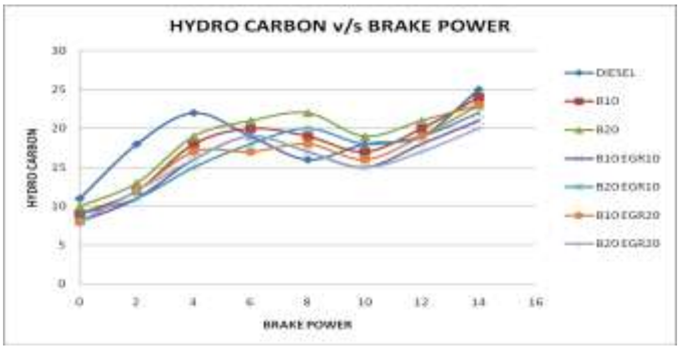

Figure 4.1: Hydro carbon v/s Brake power

4.1.2 CARBON MONO-OXIDE v/s BRAKE POWER

In two ways carbon mono-oxide (CO) can be created, through an overly lean blend B10 and B20 with 10 and 20 % EGR. Flame cannot propagate from end to end blend in overly lean blends; consequently fuel paralysis with imperfect oxidation creators CO. The fig. 4.2 shows about decrement on average was noticed for B20 than diesel It can be attributed to higher oxygen content of biodiesel which assisted to achieve also complete combustion.

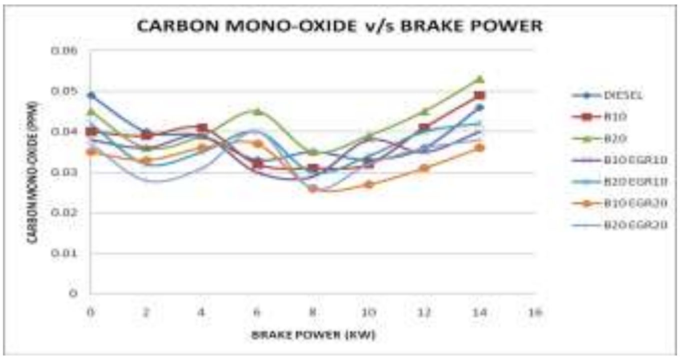

Figure 4.2: Carbon mono oxide vs Brake power

4.1.3 NOx v/s BRAKE POWER

The mechanisms which typically take part in the cylinder for NO configuration are thermal mechanism and the fuel bound nitrogen. NO configuration usually depends on oxygen concentration, air extra coefficient, in cylinder temperature and abode time. In this investigation fig.4.3 shows, B10 and B20 with 10 and 20 % EGR NOx emission on normal than diesel.

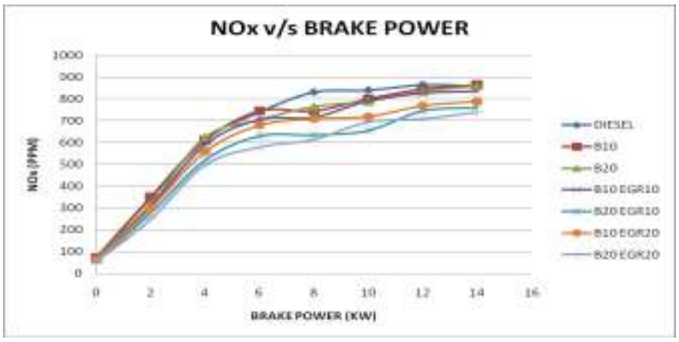

Figure 4.3: NOx vs Brake power

4.1.4 OPACITY VS BRAKE POWER

Smoke opacity indicates the stain content of the exhaust gas which is one of the main mechanisms of particulate substance on B10 and B20 with 10 and 20 % EGR. Hence, the fig.4.4 indicated that structure can be connected with fuels tendency to form particulate matter through combustion.

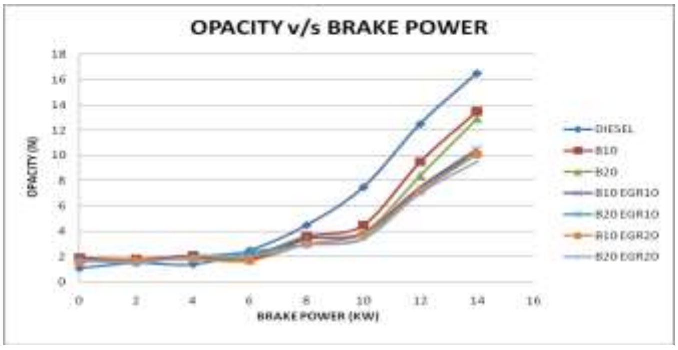

Figure 4.4: Opacity vs Brake power

4.2 PERFORMANCE

4.2.1 BRAKE THERMAL EFFICIENCY v/s BRAKE POWER

The assessment Brake Thermal Efficiency with Brake Power is shown in fig.4.5 Thermal Efficiency is the ratio of brake power rising to the energy generated by fuel Injected. In this tentative work to utilize in single cylinder four stock diesel engines in dissimilar kind of fuel and get as much as different value of Brake Thermal Efficiency of pure diesel and B10 and B20 blended biodiesel with 10% and 20% EGR.

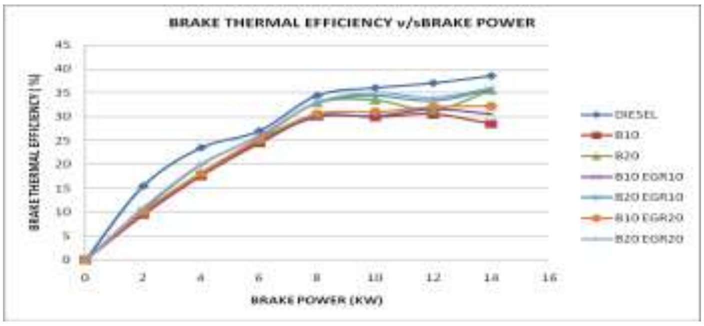

Figure 4.5: Brake thermal efficiency vs Brake power

4.2.2 BRAKE SPECIFIC FUEL CONSUMPTION v/s BRAKE POWER

The fig.4.6 shows the Brake Specific Fuel Consumption for all test fuel at totally different brake power at compression ignition engine. Brake Specific Fuel Consumption for blend Diesel to biodiesel B10 and B20 with 100% and 200th EGR decreased by concentration respectively additionally diesel.

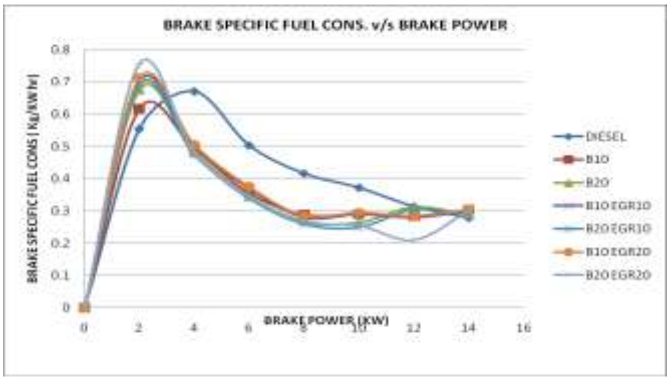

Figure 4.6: Brake specific fuel consumption vs Brake Power

5.1. CONCLUTION

The best blend in each fuel blends was again tested with different EGR(10% and 20%) rates to evaluate the best one in terms of performance characteristics and emissions.

Heat unleash rate examine disclosed some noteworthy options of combustion mechanisms, that progressive the performance and emissions for diesel biodiesel B10 and B20 with 10% EGR, and 20% EGR. Thus, the subsequent conclusions square measure peaked:

- The value of hydrocarbon emission observed petroleum diesel emitted high amount of unburned HC then B20 blended biodiesel and low unburned HC content emitted on B20 with 20% EGR is 8 to 20 ppm as increasing the load.
- The value of carbon mono-oxide emission observed petroleum diesel emitted high to low amount of carbon mono oxide then B20 blended biodiesel with 20% EGR and B20 with 100% EGR is good 0.037to 0.038 ppm as increasing the load.
- The value of nitrogen oxide emission observed B20 with 20% EGR is emitted on low amount of nitrogen oxide (NOx) 55 to740 ppm.
- The value of smoke opacity of petroleum diesel is found to be 1.1 to 16.5 N,B10 is found to be 1.9 to 13.5 N, B20 is found to be 1.7 to 12.9 N, B10 with 10% EGR is found to be1.7 to 10.5 N, B20 with 10% EGR is found to be 1.8 to 10.4 N, B10 with 20% EGR is found to be 1.6 to 10.5 N, B20 with 20% EGR is found to be 1.7 to 9.5 N, now i can say B10 with 20% EGR and B20 with 20% EGR is good emitted low amount of smoke opacity content.
- Brake thermal efficiencies are increased with increase in load with or without exhaust gas recirculation (EGR) at lower load.
- The brake specific fuel consumptions are lower for all loading conditions when operated with exhaust gas recirculation (EGR) and vice versa.

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