"Engine performance and emission characteristics of single cylinder diesel engine working on different plastic fuel blends produced from catalytic pyrolysis of different waste plastics"

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ABSTRACT: *As we know that Increase in energy demand, stringent emission norms and depletion of oil resources have led the researchers to find alternative fuels for internal combustion engines. On the other hand waste plastic pose a very serious environment challenge because of their disposal problems all over the world. Plastics have now become indispensable materials in the modern world and application in the industrial field is continually increasing. In this context, waste plastic solid is currently receiving renewed interest. The properties of the oil derived from waste plastics were analyzed and compared with the petroleum products and found that it has properties similar to that of diesel. In the present work, waste plastic oil was used as an alternate fuel in a DI diesel engine without any modification.*

In this paper an attempt has been made to investigate the conversion of waste plastic into liquid fuel by using catalytic pyrolysis process is carried out, a pyrolysis unit is Designed, fabricated and evaluated for various kinds of plastic wastes, properties of liquid Fuels obtained are determined. Blending with diesel fuel is done. Engine performance and emission characteristics studies are carried out in single cylinder diesel engine for different plastic blends

Key Words: *Biofuel, Diesel fuel , Central Pollution Control Board (CPCB), Low density polyethylene (LDPE), Break specific fuel consumption (BSFC).*

I. A. Introduction

As world is growing, transport becomes essential part of life. The biggest problem is the growing population & depletion of fossil fuel. About 100 years ago, the major source of energy shifted from recent solar to fossil fuels. This necessitates the search for alternative of oil as energy source. Biodiesel is an alternative fuel for diesel engine. Worldwide plastics production increases 80 million tons every year. Global production and consumption of plastics have increased, from less than 5 million tons in the year 1950 to 260 million tons in the year 2007 [2]. Of those over one third is being used for packaging, while rest is used for other sectors. Plastic production has increased by more than 500% over the past 30 years. Per capita consumption of plastics will increase by more than 50% during the next decades. Plastic production requires large amounts of resources, primarily fossil fuels and 8% of the world's annual oil production is used in the production of plastics. Potentially harmful chemicals are added as stabilizers or colorants. Many of these have not undergone environmental risk assessment and their impact on human health and environment is currently uncertain. Worldwide municipal sites like shops or malls had the largest proportion of plastic rubbish items. Ocean soup swirling the debris of plastics trash in the Pacific Ocean has now grown to a size that is twice as large as the continental US. In 2006, 11.5 million of tons of plastics were wasted in the landfill [3].

Most plastics are non-biodegradable and they take long time to break down in landfill, estimated to be more than a century. Plastic waste also has a detrimental impact on wild life; plastic waste in the oceans is estimated to cause the death of more than a million seabirds and more than 100,000 marine mammals every year (US Environmental Program Estimate). Along with this hundreds of thousands of sea turtles, whalesand other marine mammals die every year eating discarded waste plastic bags mistaken for food. Setting up intermediate treatment plants for waste plastic, such as, plastic incineration, recycle, or obtaining the landfill for reclamation is difficult [3].Therefore it is necessary to use a wastes plastic to avoid such problems and converted into useful bio diesel compounds by different methods.

I.B. SURVEY ON PLASTICS WASTES

As per the estimate by Central Pollution Control Board (CPCB) the plastic consumption in India, is 8 million tons per annum and about 5.7 million tons of plastic is converted into waste annually (Rathi, 2006).The increase in production and consumption of plastic materials results in a constant plastic waste increase

(UNEP, 2009). As a consequence in 2007, more than 250 million tons of plastic waste was produced (Jovanovic et al. 2009). Plastic materials are predominantly not biodegradable and having a low density makes them unfit for disposal in landfills (Aguado et al., 2007). Norway and Switzerland produced about 24.9 megatonnes of plastic waste (Mudgal et al., 2011). In 2009, around 230 million tonnes of plastic were produced and about 25% of these plastics were used in the European Union (EU) (Mudgal et al., 2011). This global figure has been increasing by an average rate of 9% since 1950 to a peak of 245 million tonnes in 2008. Polybags and other plastics items except PET in particular have been a focus, because it has contributed to host of problems in India such as choked sewers, animal death and clogged soils.

Globally, by 2050, plastic packaging production will be more than the overall plastic volumes today, according to a report by the World Economic Forum (WEF). Plastics' share of global oil consumption is expected to more than treble to 20% between 2014 and 2050, and plastics' share of the global carbon budget will see an even steeper rise, from 1% to 15%. (Carbon budget is the amount of carbon emissions that can be allowed while maintaining a reasonable chance of limiting the temperature increase this century to 2 degree Celsius above pre-industrial levels.) An increase in recycling means a reduction in the dependence on virgin feedstock.

One of the worst consequences of plastic waste is a lot of it ends up in the ocean. Around 8 million tonnes of plastic waste enter the ocean every year, with Asian countries responsible for four-fifths of it, and at present there are 150 million tonnes in seas. The WEF report says in 2014 there was 1 kg of plastic in the ocean for every 5 kg of fish; by 2025 the ratio will worsen to one to three; and by 2050 plastic will exceed fish by weight.

From the estimation of CBCP in year 2010 to 2011around 3 hundred tones of plastic waste generated in every day.

Objectives Of The Paper

- Collection and washing of plastic waste
- Drying and Storing of plastic waste
- Design and Fabrication of pyrolysis unit.
- Conversion of plastic wastes into liquid fuel compounds.
- Evaluation of produced liquid fuel properties.
- Evaluation of performance in single cylinder diesel engine by varying injection pressure.

II. METHODS AND METHODLOGY

Following two major methods are used to converting plastic wastes into useful products.

A. Thermal pyrolysis
B. Catalytic pyrolysis

A.Thermal pyrolysis

The non-catalytic or thermal pyrolysis of plastic is a high energy, endothermic process requiring temperatures of at least 350° C–500° C.Thermal cracking or Pyrolysis, involves the degradation of the polymeric materials by heating in the absence of oxygen [1]. The process is usually conducted at temperatures between 350° C and 500° C and results in the formation of a carbonized char (solid residues) and a volatile

B. Catalytic pyrolysis

Addition of catalyst enhances the conversion and fuel quality. As compared to the purely thermal pyrolysis, the addition of catalyst in pyrolysis. Significantly lowers pyrolysis temperatures and time. A significant reduction in the degradation temperature and reaction time [1] under catalytic conditions results in an increase in the conversion rates for a wide range of polymers at much lower temperatures than with thermal pyrolysis. Narrows and provides better control over the hydrocarbon products distribution in Low density polyethylene (LDPE), High density polyethylene (HDPE), polypropylene [5] and polystyrene pyrolysis. While thermal pyrolysis, results in a broad range of hydrocarbons ranging from C5 to C28, the selectivity of products in the gasoline range (C5, C12) are much more enhanced by the presence of catalysts. Again, oils obtained by catalytic pyrolysis contain less olefins and more branched hydrocarbon and aromatic content.Increases the gaseous product yields. Under similar temperatures and reaction times, a much higher gaseous product yield is observed in the presence of a catalyst for plastic wastes [3].

In present work are Mainly two catalysts are used such as dry ash powder and dry wood powder. Dry ash powder mainly consists of carbon content that accelerate the chemical reaction and dry powder helps to catch the fire easily and enhance the conversion of plastic waste into bio fuel compounds.

C. Pyrolysisunit

Pyrolysis unit developed from MS materials with 5mm thickness. By using arc and gas welding technology unit has fabricated. The experiments carried out with high temperature and atmospheric pressure so unit must be withstanding to high temperature. Professionalthermocouples, pressure gauge and safety valves are provided to reactor. Reactor welded by using gas welding to prevent the leakage of vapours. The safe and efficient pyrolysis unit is shown in the above Fig1.

Fig 1 showsthe experimental apparatus. The design of the apparatus was deliberately kept simple in line with the aim of the project to develop a recycling approach based on basic technology. The apparatus was designed to operate at high temperatures and atmospheric pressure.The heart of the experimental apparatus was a vertical tubular reactor. Aend this enabled control mounts of plastic pellets to beaded before or during operation. . At the bottom of the reactor attached a furnace for the purpose of heating the reactor. Biomass and charcoal with blower is used as a heating source to heat the reactor. Due to increasing reactor temperature the plastic starts to evaporate, these Vapoursleaving the reactor and passed into a condenser, condenser maintained at atmospheric temperature. The cyclone separator is provided at the end of condenser to separate the gaseous and plastic liquid fuel compounds. . The gas is reused to heat the pyrolysis unit and another end of cyclone separator is connected to a flask in which the liquid hydrocarbons product was collected. Temperatures and pressure were monitored continuously by using thermocouples, and pressure gauge [1].

Fig 1: Pyrolysis unit to produce biodiesel and firing systemFig 2: Waste Plastics

I. Following bio fuel yields are obtained for waste plastic by using a catalytic paralysis process

Table -2: Liquid fuel yields by using catalytic pyrolysis process.

Type of condenser	Types of feedstock	Yield of liquid product	Residue
Spiral Tube condenser	Plastic covers	45% – 58%	4.2% – 5%
	Medicine bottles	37% - 46%	4.5% - 5.5%
	Edible oil cover	70% - 75%	5.5% -6 %

Table -3:Properties of the different plastic fuel blends

PARAMETERS	PFO	PF10	PF20	PF30	PF40	PF100
Flash point (˚C)	57	59	63	64	67	73
Fire point (˚C)	59	62	66	68	72	82
Kinematic viscosity at 40˚C (mm^2/s)	2.83	4.585	4.782	5.54	5.92	7.29
Density at 40˚c (kg/m^3)	812	815.6	817.4	818.4	818.85	821.32
Calorific value (MJ/kg)	44.81	43.07	42.71	42.64	42.21	41.112

All properties of plastic liquid fuel and its blends are tabulated in above table. Properties of plastic liquid fuel and its blends satisfy the ASTM standards of fuel properties. By considering these factors we can use this plastic liquid fuel blends as a fuel for diesel engines.

II. Plastic Liquid Fuel and Its Different Blends

Fig 3: Plastic liquid fuel with different blends

IV. Engine Performance and emission characteristics analysis

IV.1. Experimental Set-Up The engine tests were conducted on a four-stroke, single-cylinder Diesel engine whose specifications are given . The engine operated by varying injection pressure

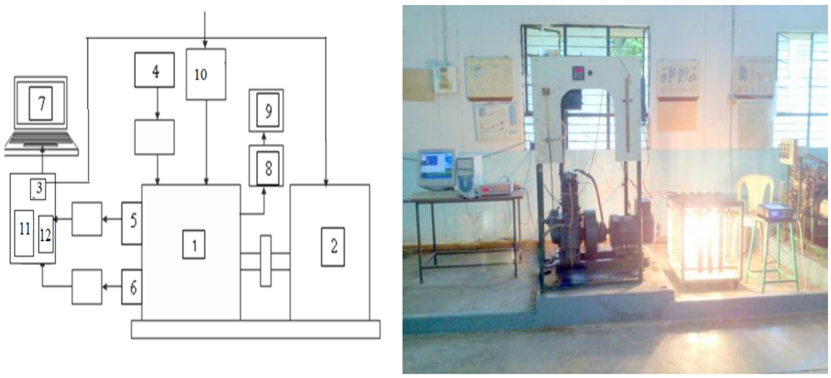

Fig.4: Schematic and of Experimental setup of diesel engine

1. Diesel engine.2.Alternator.3.Dynamometer 4.controls.5.Fuel tank. 6. Pressure pickup.7.TDC Position sensor.8.Computer.

9. Exhaust gas analyzer. 10. Exhaust temperature measurement meter. 11. Air box.12.Fuel consumption manometer

IV.2. Engine Performance

Engine operating condition at 210 bar: 1500rpm

Brake Specific Fuel Consumption:

The rate of fuel consumption divided by the rate of power production is termed as Brake specific fuel consumption

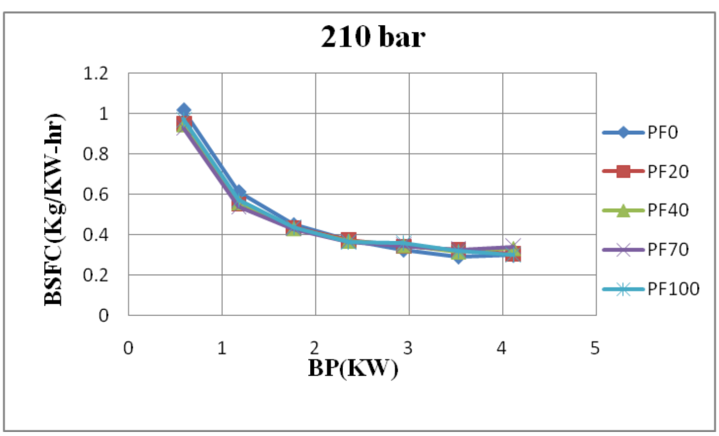

Fig.5: Variation of BSFC with brake power

Brake specific fuel consumptions descend from lower to higher Brake power level. At higher BP the brake specific fuel consumption decreased.Fig.5.Shows the variation of brake specific fuel consumption (BSFC) with BP for PF20, PF40, PF70, PF100 and diesel fuel. As the BP increases, BSFC decreases for both diesel and plastic fuel blends.

(B) Brake Thermal Efficiency

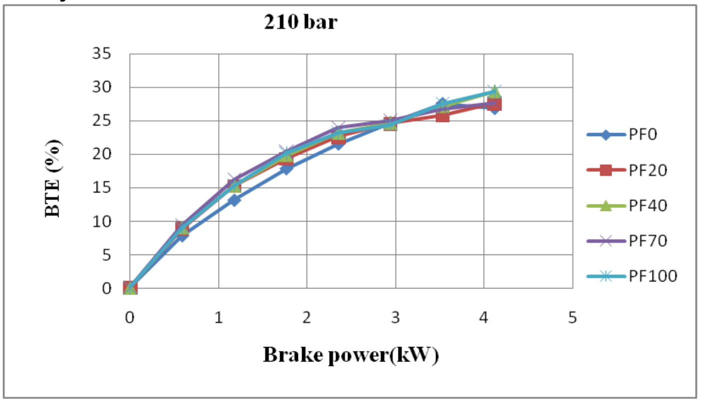

Fig.6: Variation of brake thermal efficiency with brake power

The variation of brake thermal efficiency (η_{bth}) with Brake power for diesel and plastic fuel blends is shown inFig 6. The brake thermal efficiency is maximum for the different plastic blend compare to diesel. Plastic fuels is a mixture of hydrocarbons varying from C_{10} to C_{30} having both low and heavy fractions with aromatics and oxygen. This results in smaller peak heat release rate and increases effective pressure to do work. Consequently, the work output is high and therefore the brake thermal efficiency increases. Another reason for higher brake thermal efficiency is better and complete combustion of fuel due to the oxygen present in the plastic fuel blends.

Mechanical Efficiency

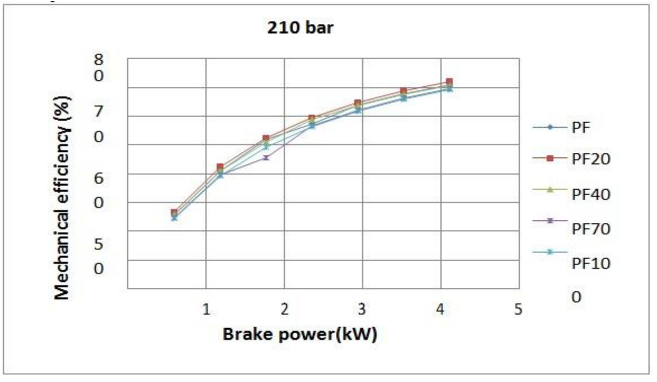

Fig 7: Variation ofMechanicalefficiency with brake power

Mechanical efficiency is defined as the ratio of brake power (delivered power) to the indicated power (power provided to the piston). The variation of Mechanical efficiency with Brake power is depicted in Fig 7 can be observed from the figure that the mechanical efficiency is 25.7% at rated power for diesel and for the waste plastic oil it is 24.42%. From the figure it is clear that mechanical efficiency of the waste plastic oil is closer to diesel.

IV.3.Emission characteristics

Carbon Monoxide

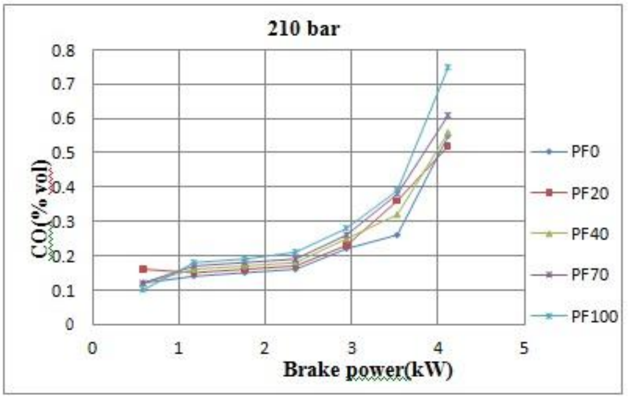

Fig.8: Variation of carbon monoxide with brake power.

The variation of carbon monoxide with Brake power is shown in Fig. 8, CO emission results from incomplete combustion. Therefore, emission of CO is greatly dependent on the air fuel ratio relative to the stoichiometric proportions. Rich combustion invariably produces CO. The CO emission maximum with the operation of PF20, PF40, PF70 and PF100 than diesel which may be attributed to poor mixture preparation. With increase in power output, the CO emission gradually increases. The CO varies from 0.12% to 0.55% for diesel fuel, for PF100 it is varies from 0.13% to 0.75%.

Hydrocarbon

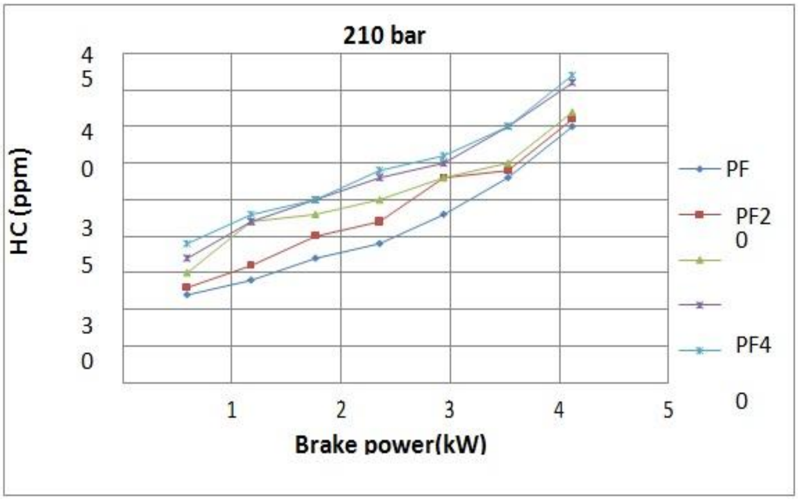

Fig.9: Variation of hydrocarbon with brake power

The variation of hydrocarbons with Brake power for different blends is shown in Fig.9. Unburned hydrocarbon varies from 12ppm to 35ppm at constant speed for diesel. In the case of PF20 blend it varies from 13ppm to 36ppm at the same operating condition and for PF40 it varies from 37 ppm to 40ppm and for PF70 it is 17ppm to 41ppm and then finally PF100 it is 19ppm to 42ppm.

From the results, it can be noticed that the concentration of the hydrocarbon of PF100 blend is marginally higher than diesel and different plastic fuel blends. The reason behind increased unburned hydrocarbon is may be due to higher fumigation presents in plastic fuel blends.

Carbon dioxide

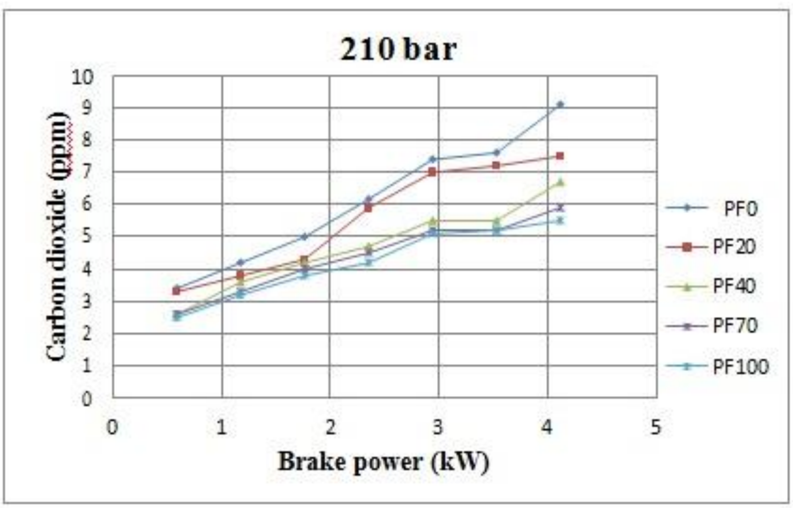

Fig.10: Variation of Carbon dioxide with brake power

Carbon dioxide occurs naturally in the atmosphere and is a normal product of combustion. Ideally, combustion of a HC fuel should produce only CO2 and water (H2O). The variation of carbon dioxide with brake power is shown in. It can be observed that in waste plastic oil it variesfrom that is for PF20 3.3pmm to 7.5ppm and for PF40 3.6ppm to 6.7ppm and for PF70 varies from2.6ppm to 5.9ppm and then finally for PF100 it is 2.5ppm to 5.5ppm. From the results, it is observed that the amount ofCO2 produced while using waste plastic oil is lower than diesel.This may be due to late burning of fuel leading to incomplete oxidationof CO [16].

Exhaust Gas Temperature

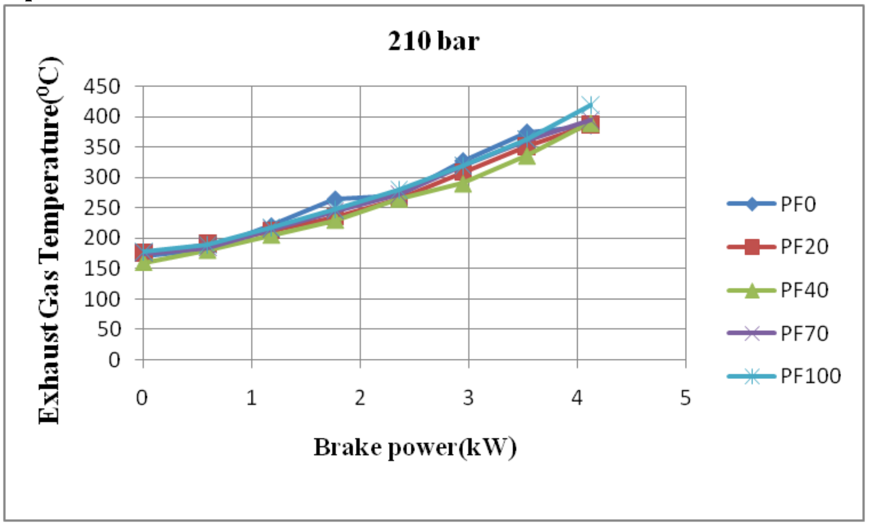

Fig.11: Variation of exhaust gas temperature with brake power

Fig.11: shows the variation of exhaust gas temperature with BP at various load conditions. It is observed that the exhaust gas temperature increases with BP because more fuel is burnt to meet the power requirement. It can be seen that in the case of PF20, PF40, PF70% and PF100% operation, the exhaust gas temperature ranges from 175^{0}C to 389^{0}C and 160^{0}C to 390^{0}C and 175^{0}c to 395^{0}c and 178^{0}C to 420^{0}C respectively whereas in the case of diesel operation it ranges from 170^{0}C to 385^{0}C. The maximum exhaust gas temperature is to 420^{0}C for blend of PF100 at an injection pressure of 210bar.

Higher exhaust gas temperature in the case of plastic fuel blends compared to diesel is due to higher heat release rate. It may also be due to the oxygen content of the plastic fuel blends which improves combustion.

V. CONCLUSIONS

By adopting this technology, efficiently convert weight of waste plastics into 65% of useful liquid hydrocarbon fuels without emitting any pollutants. It would also take care of hazardous plastic waste and reduce the import of crude oil. Depletion of non-renewable source of energy such as fossil fuels at this stage demands the improvements of this technique.

1. The biodiesel obtained from different plastics will clear and satisfactory.
2. The pyrolysis process is use to convert plastics into useful liquid fuel compounds such as biodiesel.
3. Plastic fuel and their different blends produce about lesser carbon monoxide and unburnt hydrocarbon emissions than diesel fuel, while nitrogen oxide emissions are higher than diesel fuel.
4. Produced bio fuel compounds can use for use various application.
5. The production of plastic fuel from different plastics on a large scale can be beneficial economically.
6. Results shows that by varying the injection pressure better combustion results can be obtained

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