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ANALYSIS OF LUBRICANT OIL DEGRADATION AND SOUND PRESSURE LEVEL FOR CI ENGINE USING BLEND FUELS

Faheem Ahmed Solangi[a], Liaquat Ali Memon[a], Saleem Raza Samo[a], Muhammad Ramzan Luhur[a], Aqeel Ahmed Bhutto[b*] Ali Murtaza Ansari[a]

[a]Quaid-e-Awam University of Engineering, Science and Technology Nawabshah, Sindh, Pakistan
[b]Mehran UET SZAB Campus Khairpur Mirs, Sindh, Pakistan

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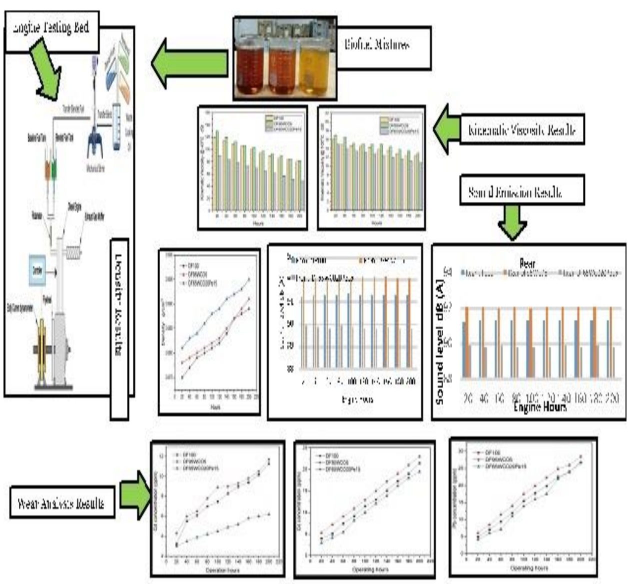
*Corresponding author
aqeelahmed@muetkhp.edu.pk

Graphical abstract



Abstract

Long-term engine running has been the subject of extensive research on the deterioration of engine oil. In contrast, it is not fully clear what effect will have by using synthetic and biofuels. In modern engines, traditional fuels and lubricants should be used to provide a research basis for characterizing novel fuel-related phenomena in them. This study makes an effort to characterize how engine lubricating oil behaves over the course of its service life through friction and wear analysis. Three different oil blends DF100, DF95WCO5, and DF65WCO20Pe15 were prepared to investigate friction and wear analysis and sound pressure level (SPL). The experimental results were extracted by using reciprocating test rig after every 20 hours. Kinematic viscosity, density, and wear metals: cadmium (Cd), cobalt (Co), and lead (Pb) were measured for the lubricant oil analysis. In general, n-pentanol aids in the reduction of engine wear debris, contamination, and lubricating oil oxidation. Further, DF65WCO20Pe15 ternary combination can be used in a diesel engine without any alteration. The SPL increased by 7.8 dB at engine speed of 1300 RPM in the case of the DF95WCO5. However, when compared to base line, the average SPL of DF65WCO20Pe15 ternary blend was 4.3 dB lower.

Keywords: Diesel Engine, Emulsion Fuel, Viscosity, Wear Debris, Sound Pressure Level

1.0 INTRODUCTION

The global economy is becoming increasingly reliant on energy sources for the transportation of commodities and passengers as a result of globalization. Diesel engines are considered prime movers owing to their high thermal efficiency, heavy duty operation, and better stability. Because of the depletion of diesel fuel resources, the scientific community has become interested in developing alternative fuel sources [1]. Studies generally show that engines perform worse when using alternative fuels, despite the environmental advantages of doing so [2-3]. The depletion of energy reserves, global population growth, and climate change all have an impact on each country's energy consumption. Modern-day utilization of fossil fuels has resulted in global ecological issues. Though, owing to their low cost in comparison to different energy sources, fossil fuels remain a primary energy source

[4-6]. The main purpose of diesel engine is to generate mechanical power, which utilize for numerous applications: electricity through heavy generators, logistics and transportation sectors [7]. The consequences of combustion in modern diesel increases fuel demand. Though, the rising need and ingesting of diesel are connected with diminishing reserve, enhancing price variation, increasing ecological as well as human problems problems [8]. Hence, a suitable substitute is needed for diesel engines [9-10]. Researchers are looking for alternative fuel sources to power diesel engines used in heavy machinery, power generation and transportation. Recycling is a crucial component of accomplishing ecological wellbeing. Many billion gallons of gutter oil are dumped globally each year [11]. Nonetheless, if not properly disposed of, waste cooking oil (WCO) poses a significant environmental risk. WCO has the ability to clog and restrain water passages and the human food chain through edible things that poses a potential health risk. WCO is also cost-effective, with all expenses incurred solely in collecting and treating data [12].

Researchers have recently become interested in reformulating WCO with alcohols because it is a modest, uncomplicated, and cost-effective method of reducing the viscosity of edible oils [13–20]. According to studies, ternary mixtures of used cooking oil with alcohol and diesel have a density close to diesel, a higher cetane number, and a low viscosity [21]. Therefore, creating execution approaches to safeguard waste cooking oil controlling becomes of greatest significance in food security. Consequently, waste cooking oil has become an inexpensive source of biofuel production and can be utilized for power generation [22-23].The physicochemical properties of WCO ought to be increased. So, the combination of waste cooking oil with improved biofuel from tropical biodiversity would change the waste cooking oil properties and produce a better performance biofuel in power generation sector and transportation sector [24].

This study aims to gain knowledge on wear analysis, sound pressure level, and lubricating oils tribological behavior. A diesel engine's wear rate, element source, and engine condition can all be predicted by looking at the concentration of metallic particles in the lubricating fluid. Iron, cobalt (Co), cadmium (Cd), and lead were the most frequent metallic elements found in lubricating oil following engine operation (Pb) [25]. By positioning Hollow cathode lamps of each element separately, an atomic absorption spectrophotometer (AAS) was built up to measure engine wear and debris. Standard solutions for lead (Pb), cobalt (Co), and cadmium (Cd) have been created.CI engine noise pollution is getting attention as a result of its association with discomfort in both operators and pedestrians. The exhaust system, combustion and valve train are the chief sources of generating noise emission in a CI engine [26-27]. To explore the noise and tribological behavior of diesel and mix fuels in stationary condition using experimental experiments on a single cylinder diesel engine. In the experimental test matrix, blend fuels such as neat diesel and DF95WCO5 and DF65WCO20Pe15 were also present.

2.0 METHODOLOGY

In this study, n-pentanol, diesel, and waste cooking oil were mixed volume for volume with the percentage composition. Miscibility tests were carried out on a variety of waste cooking oil, n-pentanol, and diesel samples. The blends were found to be stable, with no evidence of phase separation after 24 hours. Figure 1 shows the schematic diagram of processing DF100 and blended fuels for performing endurance test. In this study, an endurance test was performed in an single-cylinder CI engine for 200 hours at 1300 rpm and constant load on three fuel samples: DF100 (diesel fuel), DF95WCO5 (5% waste cooking oil and 95% DF), and DF65WCO20Pe15 (20% waste cooking oil, n-pentanol 15%, and 65% DF) as shown in Figure 2.

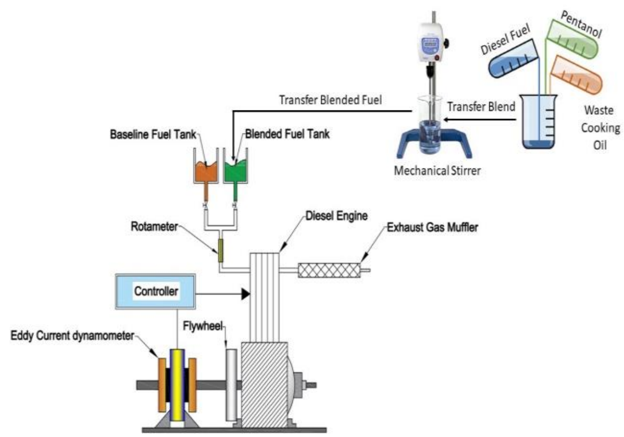


Figure 1 Experimental set up

Figure 2 Photographic view of test fuels

During endurance test the oil samples were taken at the interval of 20 hours on each fuel to assess the viscosity, density, and wear analysis in order to explore the impact of DF100 and its blends on the engine lubricate oil. The presence of wear contaminations in oil samples were checked using an atomic absorption spectrophotometer (AAS). The elements Cadmium (Cd), Cobalt (Co), and Lead (Pb) were among the many various standards produced. Element-specific hollow cathode lamps had to be installed in order to set up the AAS. In this research work, three different fuel blends as shown in Table 1 were used for investigating sound level of the CI engine. However, the diesel fuel was considered as base fuel, and the sound level results of other two blends were compared with it.

Table 1 Fuel characterization

Properties	Diesel fuel	Waste cooking oil	N-pentanol
Viscosity Cst at 40 ºC	2.28	52	2.89
Density g/ml	0.84	900	814.4
Flash point ºC	78	271	49
Oxygen (wt %)	0	20	8.47
Calorific valve MJ/Kg	42.5	37.68	34.75
Cetane number	50	54	20

Table 2 Physiochemical properties of test fuels

Properties	DF100	DF95WC05	DF65WC020Pe15	Test method
Viscosity Cst at 40 ºC	2.28	2.34	1.95	ASTM D-88
Density g/ml	0.8350	0.8363	0.8351	ASTM D-854
Flash point ºC	78	85	94	ASTM D-92
Calorific value MJ/Kg	42.5	39	40	ASTMD240
Cetane number	50	53	55.5	ASTMD4737

The engine was initially ran without any load while its speed was kept constant. Two places, including the front and rear, each one meter distant from the test engine bed, were used to gauge the sound pressure levels. The amount of noise originating from both directions was gauged using a portable microphone. Because of its directional sensitivity, this microphone needs to be pointed directly at the subject. When the sound was coming from a single point and there were no hard objects or obstructions to cause distortion or reverberation, this type of microphone performed best.

3.0 RESULTS AND DISCUSSION

Viscosity of Engine Oil

The viscosity of engine lubricating oils is an important factor. When viscosity of the lubricating oil rises, it specifies that the lubricant is deteriorating as a result of oxidation or contamination. Equally, when it drops, it typically designates that the oil has been diluted. [28]. According to the ASTM standard, the viscosity of engine oil samples was measured at 40 ºC and 100 ºC. It was believed that the viscosity measured at 100 ºC was quite close to the typical oil temperature during engine running [29].

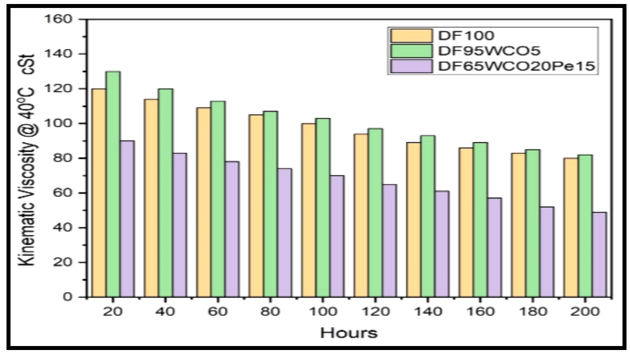


Figure 3 Kinematic viscosity at 40 ºC

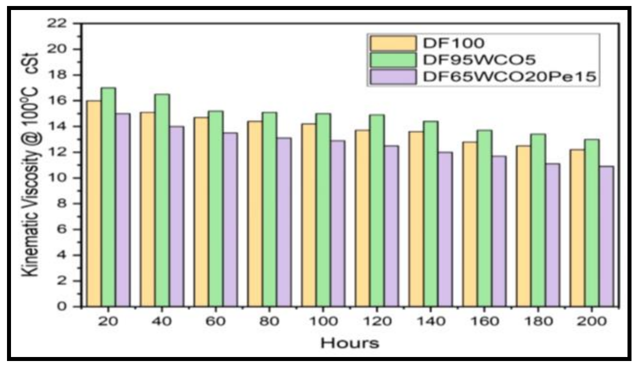


Figure 4 Kinematic viscosity at 100 ºC

Figures 3 and 4 show the findings of the experiment, which show that all lubricating oil samples' oil viscosity decreased at both 40 ºC and 100 ºC [30]. The engine lubricating oil viscosity of blend fuels during engine endurance tests, however, decreased more than it did for DF100. The crankcase oil's dilution with fuel may be to blame for this drop in lubricating oil viscosity. Therefore, it can be concluded that DF95WCO5 and DF65WCO20Pe15 resulted more decrement as compared to diesel fuel, which is mainly due to oil dilution brought on by larger size droplets.

Density of Engine Oil

The engine lubricating oil's density can be measured, and this can reveal important details about the addition of metal debris and the diluting of the engine oil with gasoline. Because of the addition of wear particles, dilution of the fuel, and increase in moisture content, used engine oil's density therefore rises [31].

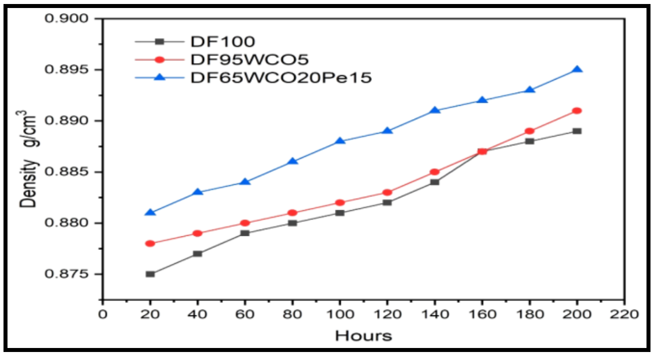


Figure 5 Engine lubricant density evaluation on different hours

Figure 5 depicts the increasing trend in engine oil sample density over time. Engine component wear is firstly occurring more quickly, and fuel dilution has also begun. As a result, when an engine runs on two blend fuels rather than diesel fuel, the combined effect of these elements has a greater impact on the rate of increased density of the engine oil. Further, the values of density obtained after engine running from 20 hrs to 200 hrs are different from the values mentioned in Table 2. This clearly evidenced that the fuel dilution was increased after using them in engine at prescribed time intervals.

Wear Analysis

Concentration of metal contamination in the lubricant oil is supportive to screen the condition and regulate the oil change time. Similarly, useful to take primary remedial work of the engine [32]. To find out more about the tribological characteristics of lubricating oil, the experiment was run steadily for a total of 200 hours [33], with each fuel sample being analyzed after an interval of 20 hours. An endurance test conducted on single cylinder diesel engine in order to ascertain various aspects of lubricating oil properties and wear estimation. The test took 200 hours to complete. The engine was first fueled with diesel and run for the required amount of time. Second, the engine was ran for the same amount of time while being fed DF95WCO5 and DF65WCO20Pe15. At regular intervals, lubricating oil samples were taken from the engine. The collected samples of lubricating oil were next tested to determine their varied characteristics. These factors monitored how well the lubricating oil performed. One of the primary functions of motor oil is lubrication. In addition to decreasing friction and wear, engine lubricant oil also transfers heat from critical engine components and shields engine parts from corrosion and oxidation [34].

Cadmium (Cd)

In the graph of various blends, as indicated in the figure 6, the investigation of the cadmium proportions in lubricating oil during long-term endurance testing is presented. The concentration of cadmium in engine oil is shown on the graph. The concentration of this element in the case of a binary blend (DF95WCO5) was found to be high as compared with other two blends. Whereas, the ternary blend offered lowest concentration of Cd as compared to DF100 and DF95WCO5. Thus, it can be concluded that the effects of n-pentanol on engine materials and wear were better when it was added to blends at a 15% concentration.

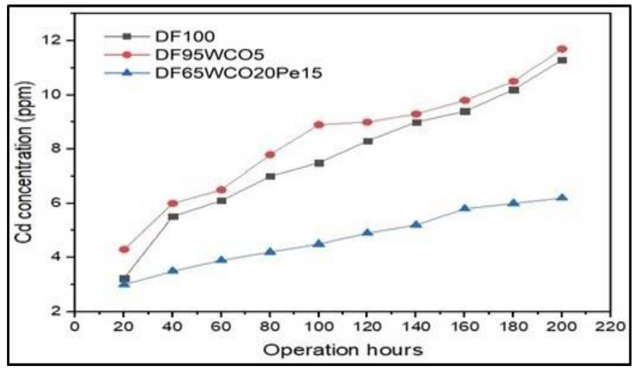


Figure 6 Cadmium Concentration of DF100 and Biofuels at Different Hours

Cobalt (Co)

The cobalt content of diesel and its blends is shown in Figure 7. The graph unequivocally demonstrates that, in terms of the number of hours lubricating oil is used, the cobalt concentration in blend fuels is lower than in diesel. The cobalt comes from the bearings. In an IC engine, cobalt in wear debris could come from cylinder linings, compression rings, gears, crankshaft wear, or bearing wear [35]. Although there is very little cobalt inside the cylinder, it is incredibly strong. As a result, only a very small amount was discovered in the engine oils, as illustrated in Figure 7. In contrast to mix fuels, the diesel-fueled engine in Figure 7 displayed less cobalt wear. The binary blend DF95WC05 resulted higher values as compared to DF100. Whereas, the ternary mix DF65WC020Pe15 resulted less cobalt as compared to DF100. Nonetheless, it can be clearly seen that the ternary mix DF65WC020Pe15 resulted least cobalt as compared to DF100 and DF95WC05. Conclusively, cobalt concentration reduced, following the use of blend fuel in the following order: DF95WCO5 > DF100 > DF65WCO20Pe15. It's possible that the acidity of blow-by air that entered the oil sump in contact with the bearing is what's causing the increase in Cobalt wear when using lubricating oil. The 200-hour engine run produced the least amount of Cobalt trash.

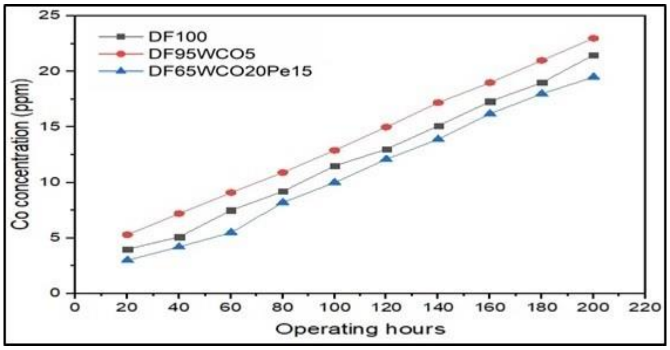


Figure 7 Cobalt Concentration of DF100 and Biofuels at Different Hours

Lead (Pb)

The probability of lead metal in the rubbishes established in the aged lubricant oil of the engine sump pledges owing to wear of component such as bearings [36].

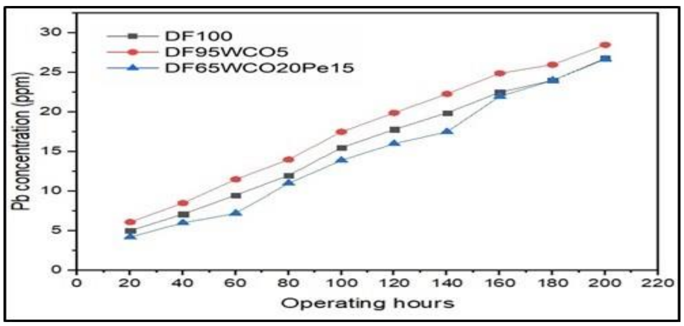


Figure 8 Lead Concentration of DF100 and Biofuels at Different Hours

Figure 8 depicts the fluctuation in lead content in diesel and biodiesel in relation to the number of usage hours of lubricating oil. According to the figure, the amount of lead found in the lubricating oil samples taken from the DF100, DF95WCO5 and DF65WCO20Pe15 is seen to be increasing with time. Whereas, in comparison of all blends with each other, the binary blend (DF95WCO5) resulted higher content of Pb, and the ternary blend (DF65WCO15Pe15) resulted least concentration. However, even though the ternary blend DF65WCO20Pe15 had a little lower concentration, it still produced results that were superior to those of engine-operated diesel fuel despite adding 15% more pentanol to the mixture. In wear debris, grease, paint, and coating are likely sources of lead.

Sound Emission Analysis

While, the better consequences concerning sound emissions were attained by petroleum diesel, when alcohol/diesel fuel blends were utilized, n-pentanol delivered nominal deviation in comparison to those of diesel fuel. This might be elucidated by the resemblance between fuel properties of both petroleum-based fuel and high carbon-chain alcohols. Its good cetane number is creating a decrease of the ignition delay period, which declines the cylinder pressure rise rate and thus, combustion noise emission [37-38]. When the engine was fueled with diesel fuel (DF100) and two blend fuels, such as DF95WCO5 and DF65WCO20Pe15 blends.

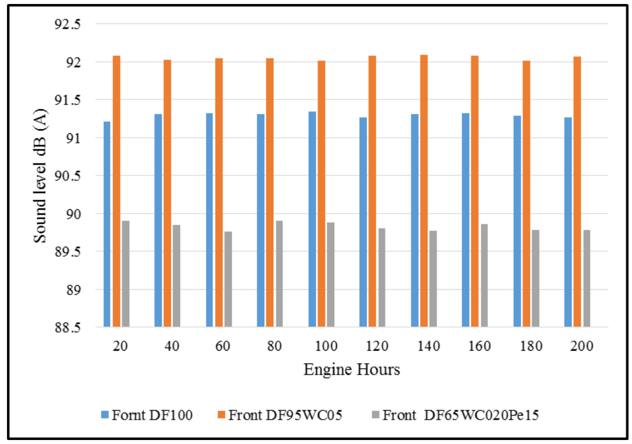


Figure 9 Front position of sound level for test fuels

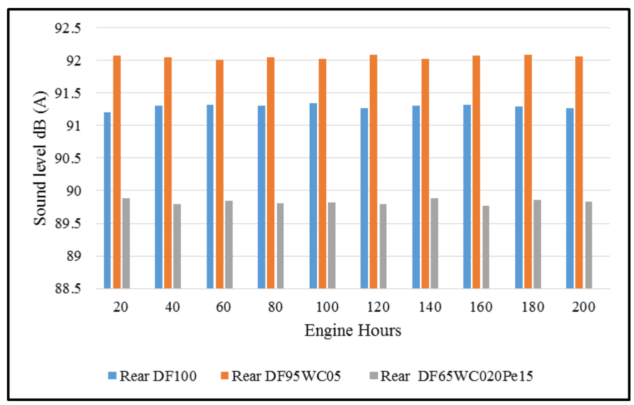


Figure 10 Rear position of sound level for test fuels

Figures 9 and 10 illustrate the sound level in different directions (Front and Rear) of the test bed together with the average of both directions. Blend fuel noise levels have decreased for a variety of reasons. The combustion phenomenon depends critically on the ignition delay. The cetane rating of a gasoline is a gauge of the quality of its ignition. It consequently has an impact on ignition delay; a higher number denotes a shorter ignition delay or earlier injection timing [39]. However, if the ignition delay period is longer (due to the fuel's lower cetane rating), it injects more diesel before it starts to ignite. As more mass explodes, the combustion pressure rises more quickly, increasing the loudness [40]. However, the increased oxygen content in blend fuels improves combustion efficiency, which may lead to a reduction in noise level. As a result, the

DF65WCO20Pe15 produced less noise compared to base line fuel.

4.0 CONCLUSION

The study carried out the investigations of the impacts of DF95WCO5, DF65WCO20Pe15 compared to DF100 on engine debris analysis and sound emissions of a compression ignition direct injection engine were conducted. Based on those trials following out comes were drawn.

In case of lubricating oil analysis, viscosity of the oil during endurance test carried out on blends DF65WCO20Pe15 showed better reduction compared to diesel fuel owing to oil dilution. For the wear analysis; wear contaminations in lubricating oil exhibited that binary blend resulted higher concentration of cadmium, cobalt and lead as compared to DF100 and ternary blend. This concluded that WCO could produce higher amount of contamination in cylinder and piston rings. For metallic constituents; the ternary blends created least proportions of metallic constituents such as cadmium, cobalt and lead compared to DF100 and binary blend. This demonstrated that the diesel and n-pentanol blend has lessor contaminations of the interior parts such as bearings, cylinder and piston rings. Finally, the engine noise emission test, binary blend produced higher sound level compared to DF100. The lowest sound level compared to DF100 was produced by ternary blend due to the influence of their respective fuel properties on decrease in ignition delay period and improved combustion efficiency due to increase in fuel oxygen content test fuel. This showed that it is suitable to use DF65WCO20Pe15 fuel for engine noise.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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