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THERMAL CRACKING OF RAPESEED OIL AS ALTERNATIVE FUEL

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ABSRTACT

Rapeseed oil was pyrolyzed in the presence of about 2% of calcium oxide up to a temperature of 450°C, a pyrolytic oil was produced that was narrow of diesel fuel. From the studies of ASTM distillation the volumetric percentage of liquid in the same boiling range for diesel fuel equal to 61% of the pyrolytic oil. The heating value of pyrolytic oil was 41.3 MJ/kg which equivalent to 93% of heating value of diesel fuel. The flash point was (80°C) which higher than diesel. This makes the pyrolytic product safer during handling and storage than diesel.

In addition thermally decomposed rapeseed oil was tested on a diesel engine and compared to diesel. The thermal efficiency (η_{th}) and brake specific fuel consumption were improved. The concentration of nitrogen oxides are less in case of the produced fuel, this in turn reduce the formation of smog due to the presence of colored NO_x. Moreover the absence of sulfur in the pyrolytic oil is another advantage to avoid corrosion problems.

Keywords: Alternative fuel –cracking -rapeseed oil .

INTRODUCTION

In the early 1930s, vegetable oils were tested on diesel engines as fuel. However, the high viscosity of vegetable oil, compared to petroleum-derived fuels, caused the engines to mal-function, impeding their application as engine fuel. Nevertheless, concerns about petroleum shortage and environmental issues have continuously promoted the development of alternative fuels from vegetable oils, animal fats, and even the restaurant grease (Ki-Teak *et al.* , 2002).

The properties of plant oils responsible for combustion problems include high viscosity and relatively high content of unsaturated fatty acids. Plant oils have viscosities approximately ten times greater than diesel fuel at a typical injector temperature of 40°C. The high viscosities alter spray characteristics, causing the formation of larger droplets, which have slower rates of penetration into the combustion chamber and penetrate to a greater distance before they are vaporized. Therefore, some plant oil may actually impinge on cylinder walls before it is consumed, resulting in increased blow by into the crankcase or gum formation on the walls. In precombustion-chamber engines, injected fuel is swirled in a vortex of air before entering the combustion chamber. This aids in the atomization of fuel and probably accounts for the better results reported for that type of engine (Hamasaki *et al.* ,1997). The production rate of rapeseed oil in the world is shown in Figure (1).

Vegetable oils are of greatest importance especially rapeseed oil, which may be used as a diesel engine fuel after extraction from seed and an appropriate transformation to rapeseed oil fuel(Jan Cvengros,1998; Kern-C *et al.* ,1997; Peterson and Hustrulid 1998; Togashi-C and Kamide,1995; Bokemann-R,1998; Togashi-C and Kamide,1999). The high viscosity of vegetable oils can bê markedly reduced by thermal cracking. During this process, the triglyceride molecules are broken into smaller fragments yielding a mixture of paraffinic and olefinic hydrocarbons which are much less viscous than the parent oil. Many investigators have studied the cracking process of vegetable oils to obtain products more suitable as fuel (D. Konwer *et al.* , 1989; A.W. Schwad *et al*, 1988; F.A. Zahera and Toman, 1993).

The aim of this work is to assess the feasibility of utilizing used a pyrolytic rapeseed oil as fuel for diesel engine.

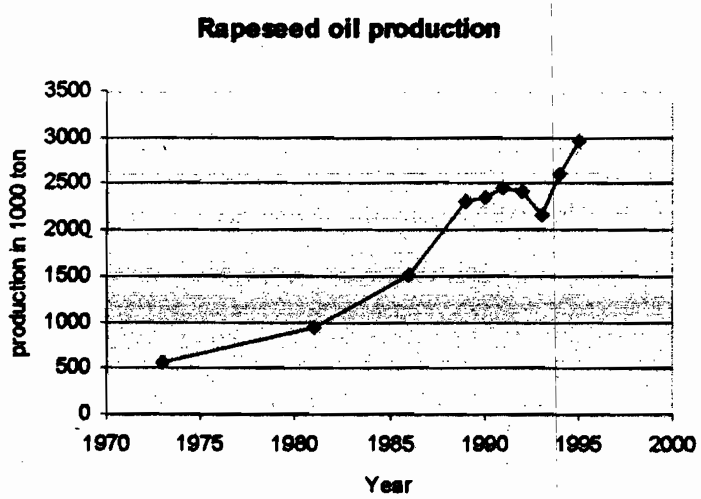
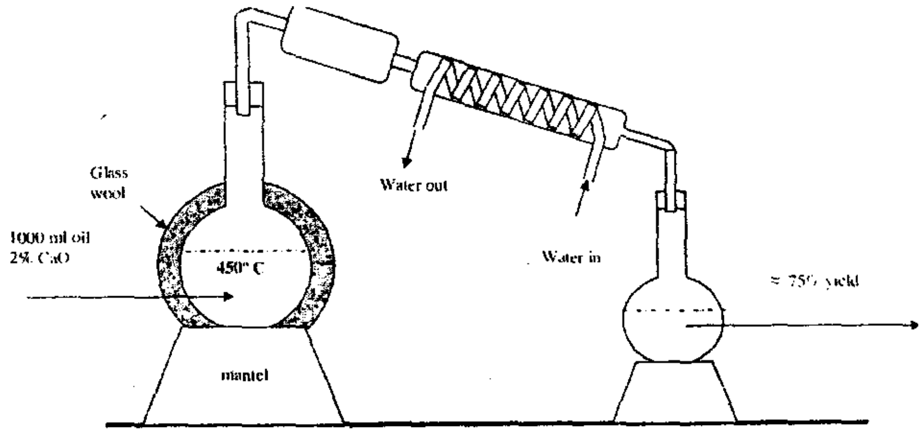


Fig (1) World production of Rapeseed Oil (1973-1995)

MATERIALS AND METHODS

Crude rapeseed oil used in this work has been kindly supplied by Cairo Co. for oil and soap.

Rapeseed oil cracking was carried out in one liter reaction flask mounted in a thermostically temperature controlled heating mantle and attached to a condensing and receiving unit Figure. (2). The oil, 500 g., was mixed with the CaO as a catalyst at a load 2% of the oil weight and the mixture was then heated to 450°C. During the thermal cracking process, the temperature of the reaction batch and the rate of distillate formation from oil cracking were monitored. The cracking period was recorded as the time elapsed between the start and end of cracked oil distillation. The weight of the collected distillate (product) was then determined which gives an estimate for the process yield (Ola A. El-Arabi, 1996).



The products obtained by oil cracking were then tested for their fuel properties using ASTM standard method for petroleum products (ASTM, 1995). These include the ASTM distillation (D 86-93), the kinematics viscosity (D445-88), the flash point (D 92-90), heat of combustion (D240-92), pour point (D97-93). A PI gravity (D287-92), sulfur percentage (D1551-68), carbon residue (D189-88), ash percent (D482-91), water content (D96-88) and cetane number (D613).

Engine test has been conducted on multicylinder compression ignition engine (CIE) Figure (3), at the Mechanical Power Department, Faculty of Engineering, Cairo University. The technical data of the engine (CIE) are listed in Table (1).

Table(1):Technical Data for Multicylinder Compression Ignition (CIE), Diesel

Capacity (liter)	**1.931**
Bore (mm)	80
Stroke (mm)	96
No. of cylinders (Z)	4
No. of strokes (n_s)	4
Maximum speed (rpm)	3500
Cooling	water
Fuel	Commercial light diesel fuel 87% C and 13% H_2 by mass

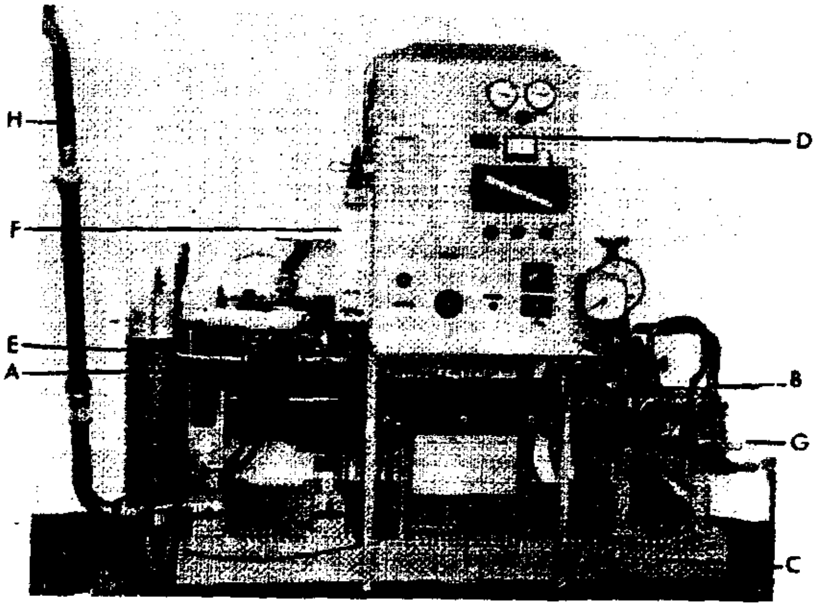


Fig. (3) A Front View of the Tecquipment Diesel Engine.
(A) The engine, (B) Dynamometer unit, (C) Bedplate,
(D) Instrumentation unit, (E) Exhaust Gas Colorimeter,
(F) Rotameter and (G) Mains supply.

The experiments were done at a constant speed of 1420 r.p.m. The inlet air flow rate during the test was 27.9 kg/hr. The brake power, BKW, the rate of fuel consumption, F, kg/hr, and the temperature of the exhaust, θex, °C were recorded(John B.Heywood, 1988). The calculation of parameters (bsfc and η_{th}) have been calculated according to the formula .

bsfc= mf / power

where bsfc: brake specific fuel consumption

mf: fuel flow rate in gm/hr

P: engine brake power in kilowatt

$$\eta_{th} = \frac{P}{m_f Q_{HV}}$$

where η_{th}: thermal efficiency

P: engine brake power in kilowatt

Q_{HV}: heating value in kJ/Sec

Environmental assessment of flue gases was also done using the LANCOM 6500. a portable flue gas measurement system Figure (4)

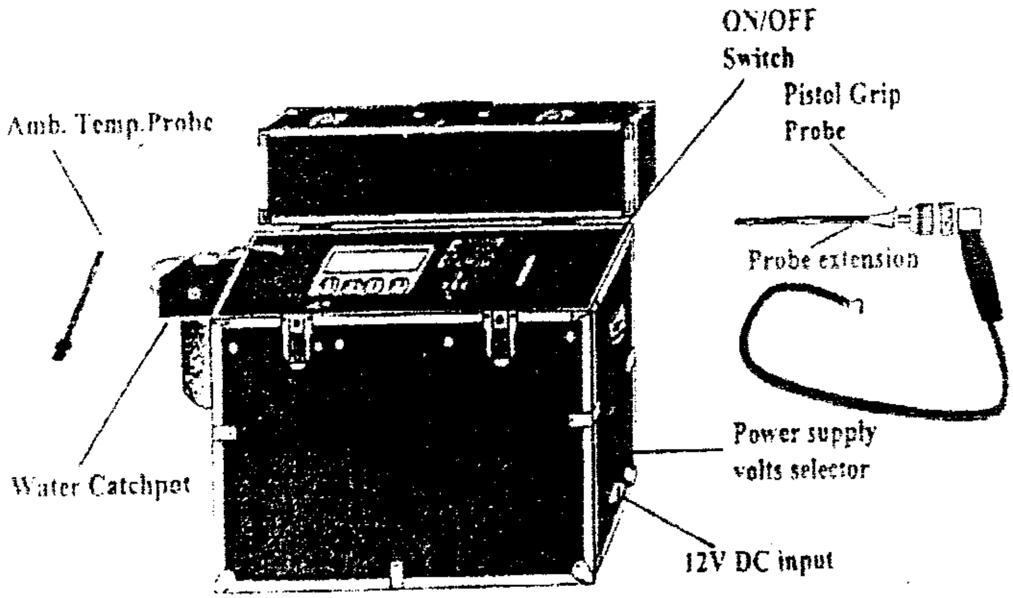


Fig (4) The LANCOM 6500A Portable Flue Gases Analyzer

RESULTS AND DISCUSSION

Oil cracking can be completed in 16 hrs using 2% CaO as a catalyst. The yield of the cracked product was 0.75 kg/kg oil using CaO as a catalyst. The cracked product was evaluated and compared with diesel fuel according to the Egyptian standard specification of a diesel fuel and also on basis of their distillation charactaristics .

It can be noticed that the physical properties of the chemically modified oil product (cracked product) is narrow of those diesel fuel. (Table 2-4)

The physical properties of the cracked products such as API gravity, specific gravity, pour point and kinematic viscosity are recorded in Table (2). It is clear that these properties are more or less similar to those of standard diesel fuel. Pour point is a very important property which affects the fuel handling, storage and its flow in the fuel lines of the engine. Fuels with low pour point (as cracked product pour point = 0.0) are thus more suitable for use during cool seasons as compared to diesel fuel. According to the Egyptian standard specification of diesel, the viscosity should not be higher than 7 c.stoke. the oil kinematic viscosity has been reduced to 6 c.stoke by cracking.

Table (2): Physical Properties of Cracked Sample of Rapeseed Oil Compared to Diesel fuel

Product	API gravity	Specific gravity	Pour Point C	Kinematic viscosity, cstoke
Cracked sample	25.470	0.898	0.00	5.967
Diesel fuel	31-41	0.82-0.87	4.5-15	≤7

The fuel content of water and sulfur as well as the carbon residue due to fuel combustion and the percentage ash are recorded in Table (3). These properties affect the engine performance and the composition of the exhaust gases which may have an adverse impact on the environment. It is clear that cracked product was free from sulfur. This is an advantage of the prepared cracked product as the presence of sulfur in the fuel will lead to the formation of SO_2 and SO_3 which may corrode the engine parts. Air pollution by sulfur oxides is a major environmental problem. This compound is harmful to plant and animal life, as well as many building materials. Another problem of great concern is acid rain, which is caused by the dissolution of sulfur oxides in atmospheric water droplets to form acidic solutions that can be very damaging when distributed in the form of rain. Acid rain is corrosive to metals, limestone, and other materials.

Recent epidemiological evidence suggests that much of the health damage caused by exposure to particulates is associated with particulate matters smaller than 10ηm. These particles penetrate most deeply into the lungs, causing a large spectrum of illnesses (e.g. asthma attack, cough, and bronchitis). Emissions of particulates include ash and soot. The cracked product was also free from non burnable material as detected by the ash% (nil). These non burnable materials, if present, may cause some abrasion of the fuel injection components. In addition, the ash can causes wear of the engine itself by increasing the overall deposit level and by adversely affecting the nature of deposits.

Table (3) : Water content, sulfur content, ash percentage and table carbon residue of cracked sample of rape seed oil compared to diesel fuel

Product	Water Content Vol %	Sulfur Content Wt %	Ash wt%	Carbon residue wt%
Cracked Sample	0.246	0.031	nil	0. 61
Diesel	≤ 0.15	≤ 1.20	≤ 0.01	≤ 0.100

Carbon deposits due to fuel combustion may cause injector coking which results in a lot of ignition troubles attributed to poor fuel atomization. The residual carbon from fuel combustion in the engine was found to be 0.61% in cracked product compared to 0.1% in diesel fuel. Water content can contribute to filter blocking and cause corrosion of the injection system components. Water content of the cracked product (0.246%) was higher than allowable limits of diesel (≤0.15%). The fuel properties which are considered very important in connection with the output power, combustion noise and handling safety are calorific value, cetane number and flash point respectively. These properties are listed in Table (4).

The flash point of cracked product (80°C) was higher than diesel (≥55°C). This make the cracked product safer during handling and storage than the diesel fuel. The heating value of the cracked product was 41.3 MJ/kg compared to 44.3 MJ/kg in case of diesel fuel. It is expected therefore that the power that can be produced from an engine under constant running condition using this product will be lower than that using diesel fuel. In addition it can be seen that the calculated cetane number of cracked product is close to that standard diesel fuel. This indicates that cracked product produce similar combustion noise as diesel fuel.

Table (4):Heating Value, Flash Point and Cetane Number of Cracked Sample compared to Diesel Fuel

Product	Heating value, MJ/kg	Heating value compared to diesel	Flash Point, C	Cetane number
Cracked Sample	41.3	0.932	80 C	53
Diesel fuel	44.3	1	≥ 55	≥ 55

The results of the ASTM distillation of cracked oil product are listed in Table (5-7) and Figure (5).

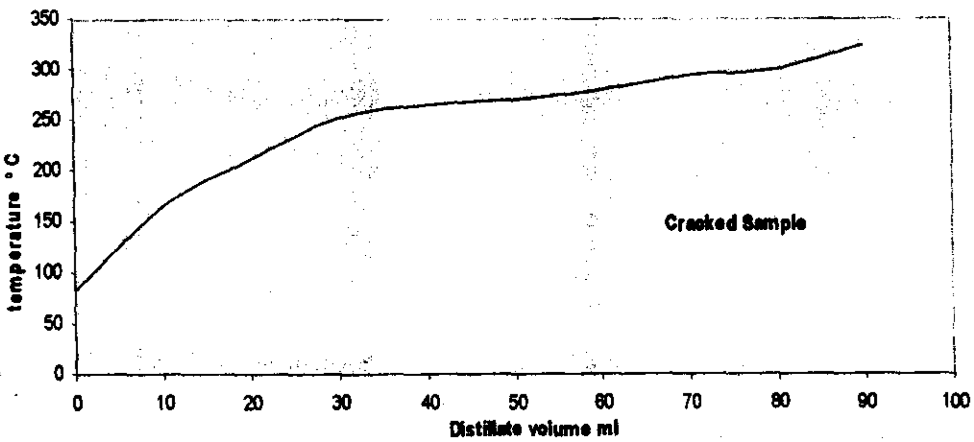


Fig (5) ASTM Distillation Curve of Cracked Rapeseed Oil Sample Using 2% CaO as Catalyst

Table (5) ASTM Distillation for Cracked Sample

Distillate volume(ml)	Cracked sample
IBP	83
10	165
20	212
30	252
40	265
50	270
60	280
70	295
80	300
90	325
Recovery	88%
Residue	10%
Loss	2%

It is evident that the 50% point, known as the mid-boiling point was 270°C for the cracked oil. Thus the cracked product has mid-point within the recommended range for the majority of automotive type of diesel engine (232-280°C)(Ola A. El-Arabi, 1996). It can be also observed that cracked product has its 90% point (325°C) at close temperatures ranging between 320-330°C. This indicates that the carbon residue from the ignition of cracked product will be similar to diesel. In addition the 10% point of cracked product was 165°C. This indicates that the ignition starting quality of cracked product will be better than diesel (Table 6).

Table(6):The Distillation Temperature of the 10,50,,90% Cuts of Cracked Rapeseed Oil

Distilled volume	Temperature, °C
10%	165
50%	270
90%	325

The ATSM distillation curve has been also used to determine the product content of the fraction which have similar boiling range as diesel, kerosene and gasoline in addition to its content of the components boiling over 350°C (as fraction D in cracked sample). The boiling range of gasoline, kerosene and diesel were taken as 35-180°C (as fraction A in cracked sample), 1 80-250°C (as fraction B in cracked sample) and 230-350°C (as fraction C in cracked sample) respectively. The volumetric percentage of each of those four fractions in the cracked product is listed in Table (7).

Table (7): Composition of the Light and Heavy Fraction of Cracked rapeseed Oil

Sample	Fraction A	Fraction B	Fraction C	Fraction D
Cracked sample	13	17	61	0

It is obvious that the fraction which has boiling range similar to diesel fuel constitutes the major fraction 61% in the cracked product.

Results of engine testing and the environmental assessment of cracked rapeseed oil was done in four cylinder compression ignition engine (CIE) when fuelled with the prepared cracked oil and compared to that when fuelled with standard diesel. The results are shown in Table (8). When using cracked product the thermal efficiency (η_{th}) were improved (32.83%) compared to 26.7% using pure diesel. The brake specific fuel consumption (bsfc) were 273 g/kw.hr compared to 336g/kw.hr using pure diesel fuel.

Table (8): Results of Engine Testing of Diesel Fuel and Cracked Sample of Rapeseed Oil (RPM=1420)

Fuel	θ_{ex}	BKW,kw	F, kg/hr	bsfc, g/kw.hr	η_{thb}
Diesel	168	4.76	1.6	336	26.70%
Cracked sample	134	4.76	1.3	273	32.83%

θ_{ex} : The exhaust temperature, °C   BKW : Brake Power, kilowatt
F : Fuel consumption, kg/hr   bsfc : Brake specific fuel consumption, g/kw.hr
η_{thb} : Brake thermal efficiency

However, the results of the analysis of the combustion exhaust are listed in Table (9) and Figure (6).

Table (9): Percentage of Some Parameters for Burned Cracked Sample and Diesel

Fuel	Percentage		
	CO_2	O_2	Water
Diesel	5.28	13.82	0.00
Cracked sample	4.23	15.22	0.00

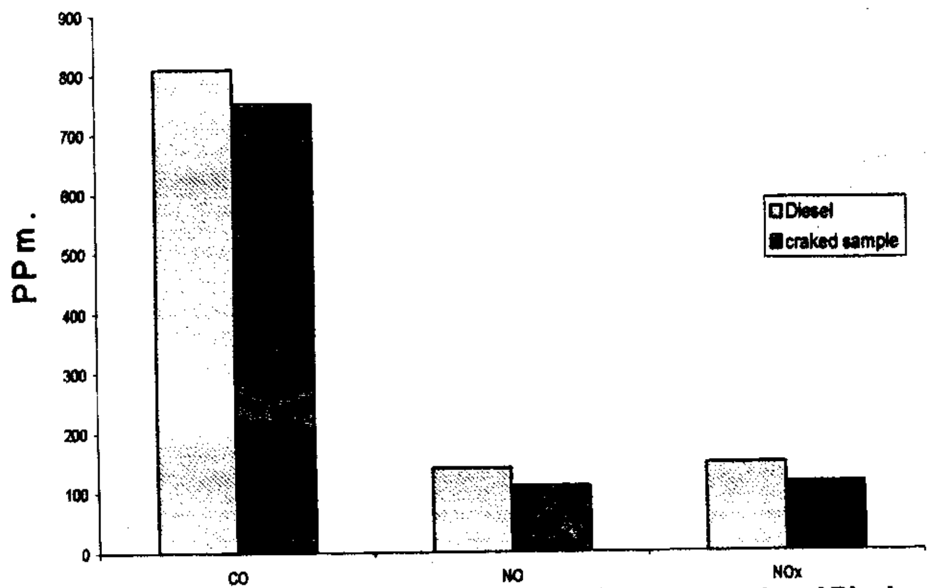


Fig (6) Concentration of Some Parameters for Burned Cracked Sample and Diesel

The results showed that the percentage of corrosive gases (NO, NO_x) in the exhaust of cracked products are much lower (NO = 110 ppm, NO_x = 115 ppm), than that of diesel (NO = 141 ppm, NO_x = 148 ppm). This will be reflected less corrosion of engine parts as well as less environmental pollution. Moreover the absence of sulfur in the pyrolytic oil is another advantage to avoid corrosion problems.

CONCLUSION

1) The products obtained by cracking are less viscous than diesel fuel. Thus they can be atomized more efficiently with more efficient combustion
2) The heating value of cracked product equivalent to 93 % of heating value of diesel fuel.
3) It is better than diesel from the environmental point of view. The concentration of nitrogen oxides are less in case of the produced fuel than the diesel fuel, this in turn reduce the formation of smog due to the presence of colored NO_2 oxides. Moreover the absence of sulfur in the rapeseed plant oil compared to the mineral oil (diesel) is another advantage to avoid corrosion problems and emission of harmful sulfur from combustion.

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التكسير الحراري لزيت الشلجم لاستخدامه كوقود

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الاستفاده من زيت الشلجم كوقود بديل من بدائل السولار المستخدم في ماكينات الديزل. من المتوقع إنتاج زيت الشلجم في مصر كغذاء و ذلك بعد معالجته حتى يتوافق مع الشروط الصحيه الغذائيه حيث اشترطت المواصفات القياسيه المصريه و الصادره عن الهيئه المصريه العامه للتوحيد القياسي و جودة الإنتاج ألا يتعدي نسبه حمض الايروسيك عن ٢%. وكان من الضروري البحث في استخدامه استخدام آخر بدون معالجه حتى نستفيد منه استفاده كامله.

من المشكلات المعروفه في استخدام الزيت النباتي كوقود اللزوجه العاليه التي تتسبب في كثير من الخسائر في حاله احتراقه و منها انسداد الفتحات و ترسب الكربون علي أجزاء الماكينه ولذلك يمكن معالجته بالتكسير الحراري باستخدام أكسيد الكالسيوم (٢%) كعامل حفاز.

وقد ينتج من هذا التكسير منتج له قيمه حراريه تساوى ٩٣% من القيمه الحراريه للديزل بالاضافه إلى أن قياس التقييم البيني و القدره علي تشغيل ماكينات الديزل كانت له نتائج افضل من كفاءه الماكينه عند استخدام الديزل. هذا و ان الاكاسيد النيتروجينيه الناتجة من الاحتراق عند استخدام هذا المنتج اقل من الاكاسيد النيتروجينيه عند استخدام الديزل و هذا يقلل من عمليه التلوث الناتجه عن احتراق الوقود بالاضافه إلى أن الاكاسيد الكبريتيه تكاد تكون منعدمه في هذا المنتج.