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THE THERMAL BEHAVIOR OF THE COAL-WATER- FUEL (CWF)

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ABSTRACT: *Large deposits of coal in the world enable to utilize in composite fuel with water and diesel, which help reducing the demand of petroleum fuels. This composite used in different thermal machines, especially in plant combustion engines with no change in the fuel combustion technology. A carbon powder containing small molecules dissolved in water in - coal-water- fuel (CWF) -is good fuel for applying in large capacity engines in electrical plants. This paper gives necessary information about obtaining of water-coal emulsion including its physical properties and focuses on the action of sea water vapor in CWF. The experimental tests indicate a higher thermal efficiency of engine fueled by water–coal-fuel emulsion than engine fueled by black oil lonely. The increased emission of CO_2 or NO_x can be reduced in the plants simply by chemical reduction. The paper explains the appropriate ratios leading to effective combustion process. This paper is a certain challenge for finding a new fuel sources as a competition for crude oil. The thermal behavior of different ratios of composite fuel were measured in thermo-gravimetric station under normal atmosphere pressure, to determine the appropriate ratio of CWF. The results show that the addition of 30% sea water as vapor in CWF decrease NOx and gives high thermal efficient.*

KEYWORDS: Coal, Water, Fuel, CWF, Sea Water, Vapor, SLBS, Carbamide.

INTRODUCTION

Fluctuations in prices of petroleum products leads to influence the economy of poor countries, especially in the non-oil-producing countries. In order to decrease the dependence of numerous countries on petroleum, many works have been done on heavy-duty diesel engines fuelled by coal or water-coal emulsion (Nelson et al., 1985). The works done by General Electric on two cylinder test engine fuelled by micronized coal-water-slurry (CWS) with very small diameter of pulverized coal (d<5 μm) was very successful ***(Mitianiec, (2016))***. Many problems appear with applying of CWS predominant of coal atoms in the fuel, such engines emit also higher amount of carbon dioxide to atmosphere in comparison to engines working on diesel oil. The main benefits from CWS is cheaper fuel and high enough caloric and using coal to fuel diesel engines could provide a secure and efficient power generation technology. The first practical use of the CWS as a fuel in power plants is composed by adding coal powder in the fuel oil to alleviate of consumption. Which will maintaining combustion technology without change ***(G. Stogney, 1991).*** An interesting potential market for CWS has been found to exist in the European Economic Community and the industrial, the utility and the residential/commercial sectors allow the replacement of substantial amounts of traditional oil-derived and gaseous fuels with CWS ***(B. Variali,1989).***

The coal is dissolved in the diesel fuel and water that leads to speed coal combustion and converts it into a gas .Combustion of surfaces of coal molecules takes place together with water evaporation (***Wilson, ,2006, Kalpesh , 2012***).

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Figure (1) illustrate the feasibility of composite fuel when adding the coal, it's clear that the cost increase by increasing the coal content, 10 % coal content is the optimum percent to preserve the cost of the composite fuel and its preparation cost.

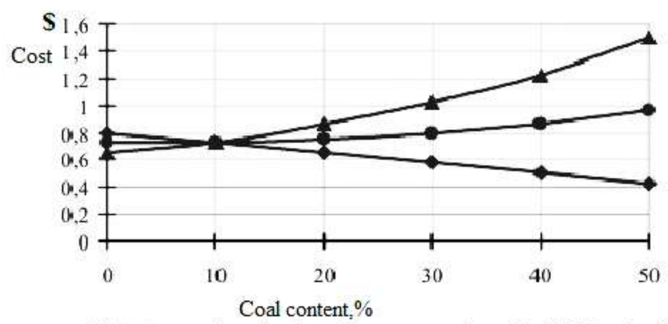

Fig 1 Economic evaluation of the consumption of fuel CSF, when it's added coal

The aim of this work is to improve the combustion technology of CWF -based on emulsified hydrocarbon fuels (black oil or diesel) with additives "coal dust". The pumping of sea water vapor in CWF inclusions in the form of micro droplets substantially affects the mechanism of evolution of the CWF drop. It is known that the effect of water, water additives may also be considered as additives activator substance, is shown in the form of "micro explosions" followed by dispersing CWF droplets. The described effect is observed because the boiling point of water usually below the boiling point of the liquid base CWF. In case of introducing of the activator in CWF substances (in our case, carbamide), the process of thermal decomposition is observed at a higher temperature in the second stage of evolution CWF primary droplets and does not represent micro explosions.

EXPERIMENTAL

Materials

1. Coal powder (about 75 microns) Contain on 39 % fixed Carbon which gives heating value of coal.
2. Sea water from the Mediterranean Sea which is one of the warmest and it most saline seas of the world and Rapid evaporation is responsible for the sea's high salinity (38.40g/l)
3. Fuel Diesel heat of combustion 4.01×10^{4} kJ / kg and mass fraction of sulfur 0.50 % , Black oil heat of combustion 9.53×10^{3} kJ / kg mass fraction of sulfur 1.20 %
4. Carbamide are supplied from Merck and used as such.
5. Sodium lauryl benzene sulfonate (SLBS) are supplied from Merck and used as such.

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Preparation of coal-water fuel (CWF)

To prepare CWF mixer (8000 rev / min) is used for mixing carbon powder in admixture, then sea water vapor is pumped. Sodium lauryl benzene sulfonate (SLBS) is added with percent up to 0.50% to emulsify the mixture. Thorough stirring for half hour, the suspension was adjusted to a homogeneous mass state, then measuring the time at the end of the mixing procedure, the time of deposition of coal powder in the fuel is shown in the table (2).

Table 2. The time of deposition of coal powder in the fuel

Percentage of fuel %	**Percentage of water** %	**Start time** precipitation **(min)**	**End of time precipitation (min)**	**SLBS additive (w.t percent)**
20	80	1	4	0.00
20	80	1.5	7	1.25%
20	80	2	9	2.50%
40	60	1	24	0.00%
40	60	4	60	1.70%
40	60	20	600	4.50%
60	40	5	70	1.80%
60	40	7	360	3.40%
80	20	9	400	0.50%
90	10	4	500	125%

RESULTS AND DISCUSSION

The combustion of coal in power plants differs from that in diesel plants. The injected pulverized coal with Sea water vapor and mixed with slurry flowing into the chamber through the injector nozzles.

The nozzles should have higher diameter than for diesel oil. For that reason, usually the Combustion chamber have higher cylinder capacity.

The diesel is injected into the combustion chambers until stability. Then CWF is injected when a CWF drop gets in a hot combustion chamber there is immediate warm-up of the drop surface and water evaporation from the drop surface. Inside the drop there is a gradual warming and as the temperature is increasing the moisture evaporate rates from the interior of the drop shaped crystal explode at high temperatures in the combustion.

When the temperature will increase in the combustion chamber there is a process for the thermal destruction of CWF surface drops in the first combustion of volatiles in the fuel after the combustion of liquids will occur, and in recent Burned solids. The product of the combustion process is shown in (Table 1).

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Table 1. Combustion Processes Results of CWF (unit m. mol / kg)

Fragment	SO_3	NO	CHO	CH_2O	HCN	SO_2	O_2	NO_2	NH_3	CO	COS	N_2O	H_2S	CO_2
m. mol / kg	0.38	141	0.26	0.01	0.01	0.07	229	1.99	0.10	327	0.13	0.65	0.08	406

From viewing the thermal behavior of composite fuel drops under heating, the ignition of the fuel can be divided to three phases:

Evaporation phase, pre-combustion phase and post-combustion phase ***(Nazrinca, 1990)***. BY following-up the evaporation experiments, the physical evaporation of the composite fuel can be divided into two stages:

Stage I:

1. Evaporation of the main product;
2. The formation of the core of the entail suspension.

Stage II:

1. Combustion area with evaporation of the main product core.
2. Fragmentation of conglomerate particles dispersed from the core when adding solid activator. (Chowdhury, 1987), figure (1).

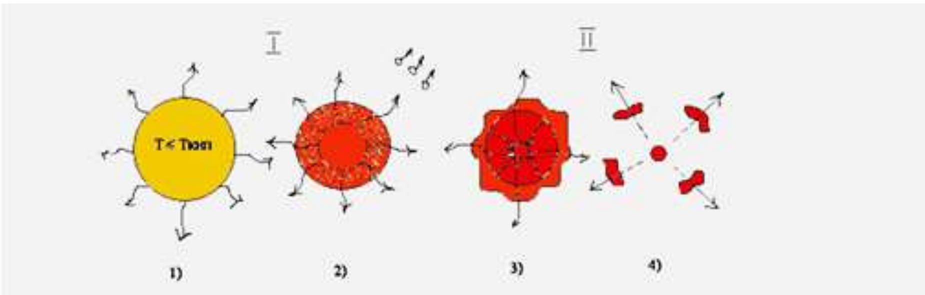

Fig.1 Mechanism of the evolution the drop

The thermal behavior of different ratios of composite fuel is followed in thermo-gravimetric station under normal atmosphere pressure, to determine the appropriate ratio of a composite fuel. **(figure 2),**

The experiments illustrate that water decrease the viscosity of composite fuel and homogenize it.

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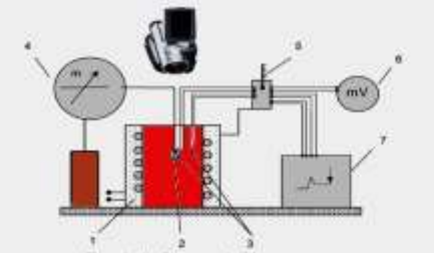

Fig 2 Station Thermogravimetric
1 – muffle furnace ; 2 – CSF sample ; 3 – Thermocouple ; 4 – Mass Scale
5 – Thermometer ; 6 – Millivoltmeter – 7 Autographic

The chemical composition of CWF including the volatile components and ash content after combustion are illustrated in table (3).

Table 3. The chemical composition of CWF

Fuel	Chemical formula	Volatiles	Ash content
Black oil	$(C_{0.875}\ H_{0.125}\ O_{0.005})$	98%	0,14%
Diesel	$(C_{0.946}H_{1.161}O_{0.002})$	98%	0,02%
Coal dust	$(C_{0.838}\ H_{0.056}\ N_{0.015}O_{0.077}S_{0.014})$	42%	19%
Sea Water	H_2O	-	-
Carbamide	$CO(NH_2)_2$	-	2%

The results of composite fuel mass changed by time is shown in Figure (3)

The figure shows the results of experiments, which follow the thermal behavior of the composite fuel based on 10% coal powder with different ratios of water.

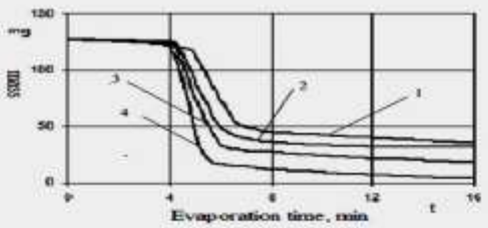

Fig 3 . composite fuel mass changed by time

1 - 80 % black oil, 10 % coal and 10 % water;
2 - 70 % black oil 10 % coal and 20 % water;
3 - 60 % black oil, 10 % coal and 30 % water;
4 - 50 % black oil, 10 % coal and 40 % of water.

From (figure 3), it can be concluded that as the percentage of water decreases as the sedimentation rate increase as well as increase the rate of the fuel vaporization. In addition, it can be observed that 70 and 80 % of diesel in the composite fuel lead to more precipitation and less thermal efficiency in the pre-combustion stage.

The experimental results of composite fuel based on diesel are shown in (figure 4): as the water percent increase, the thermal efficiency and evaporation rate of the composite fuel decrease.

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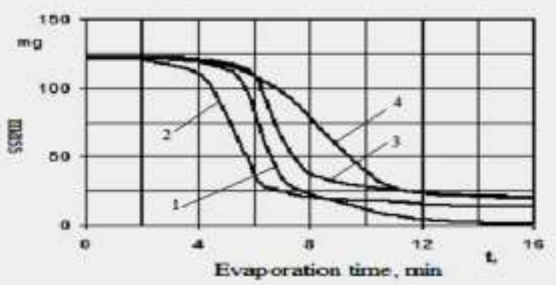

Fig 4 . composite fuel mass changed by time

1 - 90% Diesel and 10% water
2 - 80% Diesel and 20% water
3 - 60% Diesel and 40% water
4 - 40% Diesel and 60% water

The role of the activation materials

The activation materials such as carbamide combined with the coal powder at temperature above 1500 C° , this combination activate the combustion process and minimize the ignite fuel precipitants and polluted gases such as NO_X, SO_2 and CO. in addition to carbamide, calcium oxide and calcium hydroxide can be activated materials either as solution or solid powder. ***(1998, Dwiochenkov)***

Therefore, the thermal behavior of the aqueous carbamide as a solution is followed up and compared, as well as his behavior as a solid (figure 5).

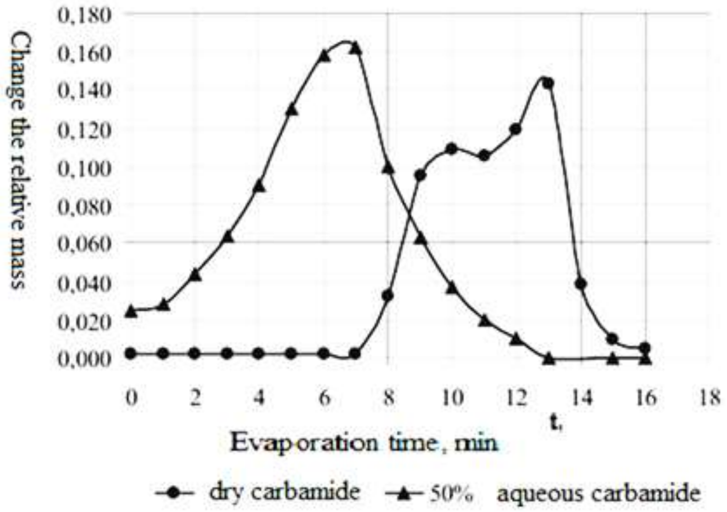

Fig 5. The change of the relative mass of the active substance versus the evaporation time in both solid state and in aqueous solution.

It clear that the precipitation of dry carbamide is faster than the aqueous solution under the same thermal condition and atmospheric pressure. As well as the period of thermal interaction of dry carbamide is longer than the aqueous one. Moreover, thermal change of dry carbamide occurs in two phases.

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The change of the relative mass of dry and aqueous solution of carbamide during a gradual raising of temperature are shown in Figures (6).

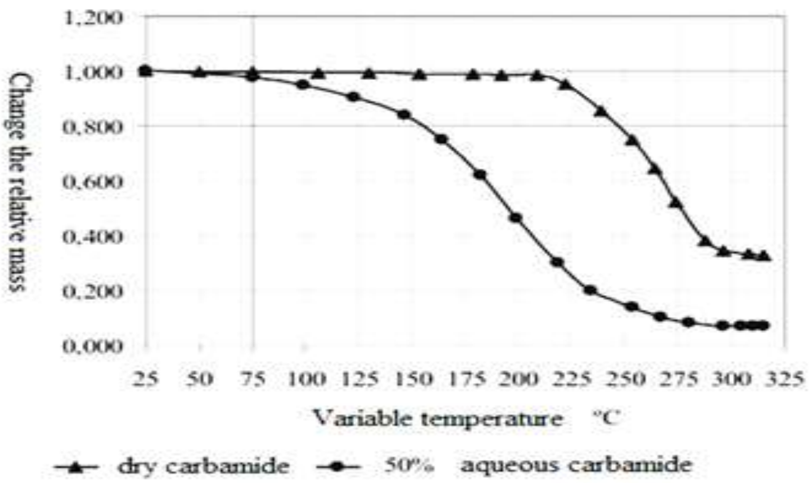

Figure (6) The change of the relative mass of carbamide during a gradual raising of temperature.

The change of the relative mass of dry and aqueous solution of carbamide during a gradual raising of temperature is showen in figure (6). The results illustrate that the aqueous solution of carbamide accelerate the thermal reaction and minimize the relative mass of the active substance.

Figure (7) shows the effect of adding carbamide in CWF at different ratios of the sea water on the change rate of the relative mass of the fuel during evaporation process, the results show that 40% aqueous solution of carbamide in composite fuel give less precipitation in addition to accelerate the changing of the relative mass.

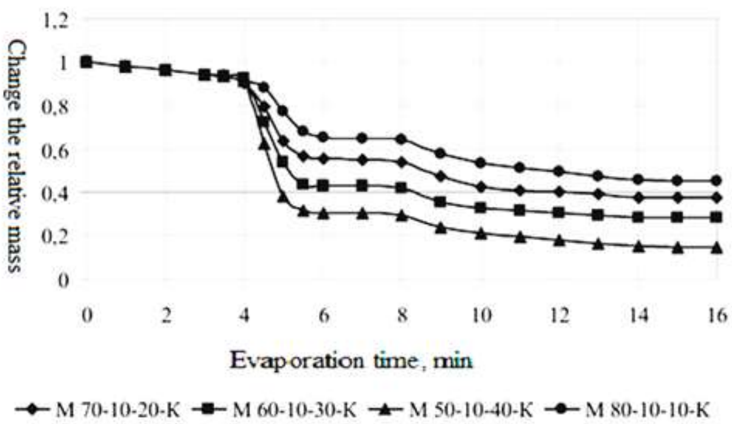

Fig (7). Effect of adding carbamide on CW

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Figure (8) shows The effect of water vapor on CWF at different ratios of water, We see that the water vapor increases the degree of combustion and accelerates the combustion process, which may refer to the high thermal capacity of vapor.

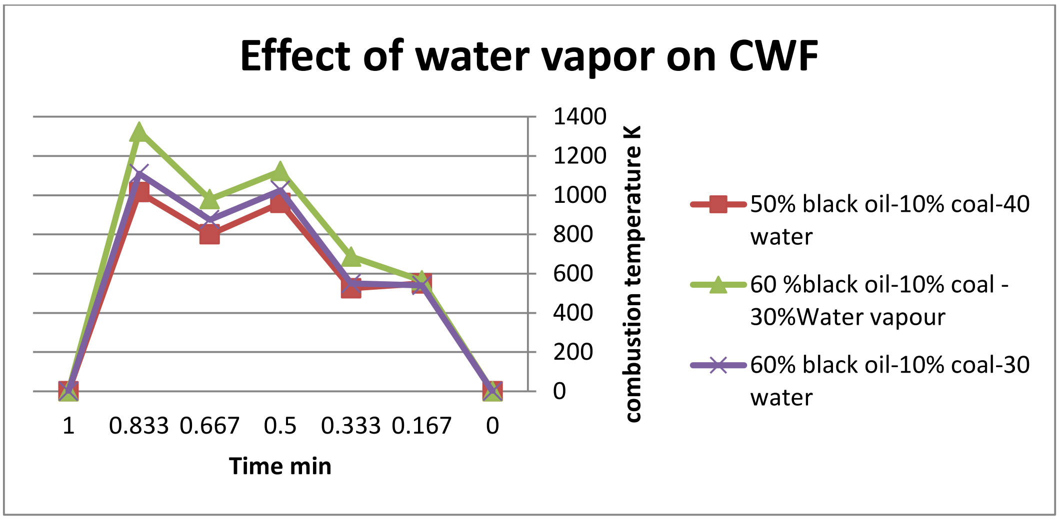

Fig (8). The effect of water vapor on CWF

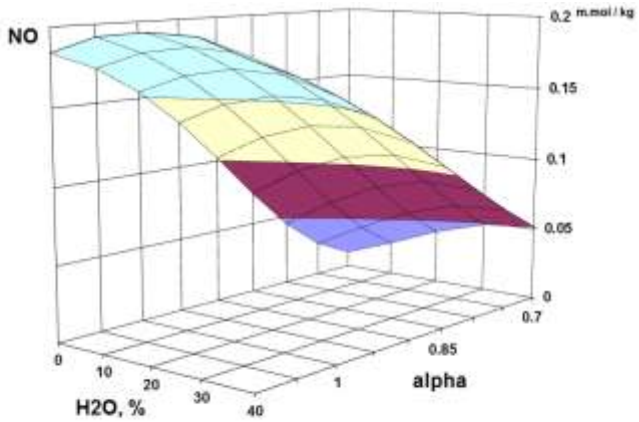

Fig 9. NO included in products of the combustion measured at different mixture fuels with versus Alpha variables.

It is clear from figure (9) that the 30% vapor seawater is the optimum percent, which produce a minimum percent of NO_X gases and the lowest coefficient of alpha.

Alpha is a coefficient incompletion air: where

$$alpha = \frac{G_{air}}{G_{fuel} * a_f}$$

G_{air}: mass air

G_{fuel}; mass fuel

a_f = 13" the amount of air in kg needed to complete burning of 1kg black oil like fuel" ***(Musalam, 2004)*.**

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CONCLUSIONS

After studying the designed coal-water fuel, some remarks can be concluded:

1. 10 % coal content is the optimum percent to preserve the cost of the composite fuel and its preparation cost.
2. The precipitation of the composite fuel contains 70-80% diesel and 10% coal powder (without carbamide) is faster and less thermal efficiency than the one with carbamide under the same condition of atmospheric pressure.
3. The thermal efficiency of the composite fuel with diesel decrease as water percent increase.
4. the physical evaporation of the composite fuel can be divided into two stages:

Stage I:

- Evaporation of the main product;
- The formation of the core of the entail suspension.

Stage II:

- Combustion area with evaporation of the main product core.
- Fragmentation of conglomerate particles dispersed from the core.

5. The aqueous solution of carbamide accelerate the thermal reaction and minimize the relative mass of the active substance.
6. The activation materials such as carbamide activate the combustion process and minimize the ignite fuel precipitants and polluted gases.
7. 40% aqueous solution of carbamide in composite fuel give less precipitation in addition to accelerate the changing of the relative mass.
8. The composite fuel is an effective alternative for oil fuel and diesel in the power plants.
9. Using the sea water as vapor increases the degree of combustion and accelerates the combustion process.
10. 30% seawater is the optimum percent, which produce a minimum percent of NO_X gases

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