METHOD FOR CRACKING HYDROCARBON PRODUCTS

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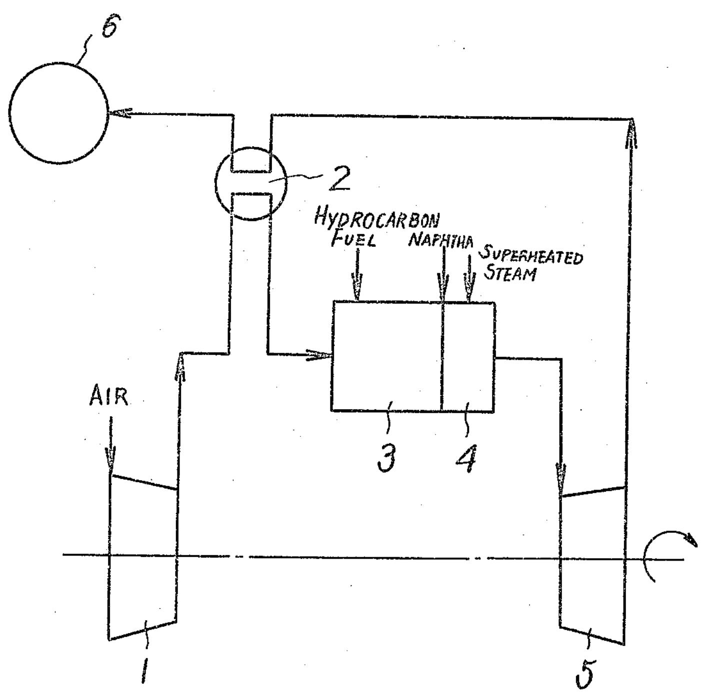

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METHOD FOR CRACKING HYDROCARBON PRODUCTS

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This invention relates to apparatus and associated methods for obtaining cracked products of a hydrocarbon substance by subjecting the substance to the combustion product of a hydrocarbon fuel to form a gaseous mixture, and thereafter carrying out quenching of the mixture in an adiabatic expansion without heat exchange.

As one of the processes for obtaining from a hydrocarbon product, the petrochemical raw materials, such as ethylene, propylene, acetylene or the like, such a method has been heretofore used wherein the hydrocarbon fuel is burned in the presence of oxygen or air in a cracking furnace. The raw material hydrocarbon is injected into a high temperature zone to carry out the cracking reaction, and the cracked gas and the combustion gas thus generated are cooled by heat-exchanging means employing a liquid coolant such as water. For improving the thermal cracking efficiency of the hydrocarbon product as well as preventing undesirable chemical change, such as polymerization of the cracked gas and the like, methods capable of increasing the cooling speed several times faster than that of the conventional heat exchanger, have been desired for a long time and wherein heat exchange employing a liquid coolant is to be avoided.

On the other hand, the plant for carrying out the thermal cracking of raw materials for petrochemical industries is extremely expensive and also from an economical viewpoint, the gas cost becomes higher due to high depreciation cost of the plant, and, therefore, large size plants have been required. If a cooling system can be utilized instead of heat exchange in order to simplify the enormous plant, and the heat content of the gas mixture consisting of the combustion gas and the cracked gas can be utilized to a maximum degree, the costs of producing petrochemical raw materials will be remarkably reduced.

It is an object of the present invention to provide a cracking method whereby the thermal cracking efficiency for hydrocarbons can be greatly improved.

It is a further object of the present invention to provide a cracking method wherein the cracked hydrocarbon is prevented from undergoing undesirable chemical reaction, such as polymerization reaction and the like.

It is still a further object of the present invention to provide a cracking method, whereby the thermal cracking of hydrocarbons can be carried out with least energy loss.

In accordance with the invention, after a suitable selection of cracking pressure and temperature has been made, the cooling of the cracked gas generated by the cracking of the said hydrocarbon is effected not by heat exchange, such as water cooling and the like, but by carrying out adiabatic expansion of the gas, resulting in an increase in the cooling effect, while simultaneously the power generated by the said adiabatic expansion can be utilized if desired.

The present invention provides a method wherein both the cracking of hydrocarbon and recovering of useful power effected by the adiabatic expansion unit are combined, and the hydrocarbon fuel undergoes combustion by use of compressed and preheated air, oxygen, or the like, wherein the raw material hydrocarbon product to be cracked undergoes thermal cracking as a result of the high temperature and pressure combustion gas formed,

the high temperature and pressure gas mixture formed during the cracking being sent to an adiabatic expansion device to cool the said gas to obtain the cracked products. Cooling is carried out at an extremely high speed for the cracked hydrocarbon and therefore any unfavorable reaction, such as polymerization reaction and the like, is completely prevented, whereby the desired cracked products are effectively obtained.

Further, according to the present invention, the energy released by the adiabatic expansion of the high temperature gas mixture of thermally cracked hydrocarbon raw material can be effectively recovered, for example, by a gas turbine, and the overall efficiency can be kept at a high degree, for example, by utilizing the turbine for the compression of air or oxygen for the combustion of the hydrocarbon material.

Furthermore, depending upon the thermal cracking reaction of hydrocarbon in the present invention, a large volume of gas having a high temperature and high value of average molecular weight can be generated, and therefore, the energy recovered efficiency can be increased in the adiabatic expansion. Further, in the present invention, if the raw material is hydrocarbon liquid, the power required for pressure increase carried out prior to heating can be greatly saved, and consequently, the output of the adiabatic expansion unit can be increased.

An embodiment of the present invention is diagrammatically illustrated in the attached drawing with regard to a naphtha cracking process, wherein a gas-turbine power generating unit is employed simultaneously.

In an open cycle gas turbine heretofore used in the industry, compressed air is increased in pressure up to about 5 atmospheres by a compressor and charged into a combustion chamber, wherein fuel is injected in an amount corresponding to that of the charged air. The temperature of the fuel is kept at about 1500° C. by subjecting it to a complete combustion. Then, a large amount of air is mixed with the high temperature combustion gas to decrease the temperature thereof to about 750° C. The gas turbine is driven by the gas at the reduced temperature of 750° C. This system is well-known in the art.

It is ideal, with respect to efficiency to directly charge the high temperature combustion gas into the gas turbine, but it is necessary in order to avoid deterioration of the turbine to decrease the temperature of the supplied gas to about 750° C.

On the other hand, when naphtha is cracked by a partial combustion method, a decrease in temperature and an increase in gas volume due to a mixing dilution and endothermic reaction of the combustion gas and the raw-material naphtha become an indispensable part in the process, and therefore, it becomes possible by a suitable selection of the cracking reaction conditions to combine the naphtha cracking method with the gas turbine drive.

The above said problems can be solved by causing the raw material naphtha to be thermally cracked by the high temperature and pressure combustion gas obtained by the combustion of hydrocarbon fuel with compressed and preheated air, oxygen or the like, the high temperature and pressure gas mixture formed by the cracking being supplied to a gas turbine. Thus the combustion gas of the fuel hydrocarbon is cooled and power is generated by the adiabatic expansion at the same time.

The temperatures and pressures of the compressed air (or oxygen), combustion gas, cracked gas and the like in this case should be preferably similar to those of the gas for driving conventional well known gas turbines. Thus, for example, the combustion gas temperature is preferably between 1300 to 1500° C., the cracked gas temperature is preferably between 700 to 800° C., and the pressure is preferably between 4 and 10 atmospheres.

This establishes the commercial adaptation of the present invention to practical applications.

The advantage of the present invention as observed in the example is such that, from the viewpoint of the hydrocarbon cracking process, the cooling effect for the cracked gas can be increased by adiabatic expansion, whereby the thermal cracking efficiency is increased. In addition, on the one hand, the heat content retained in the gas mixture can be effectively recovered as power and, on the other hand from the viewpoint of generation of power, such heat content of combustion gas as subjected to reduction in temperature from about 1500 to 750° C. without any utility can be utilized significantly.

In the drawing, numeral **1** represents an air compressor, wherein the air (or oxygen) at room temperature and atmospheric pressure is subjected to an adiabatic compression to produce compressed and heated air at a pressure of about 6 to 7 atmospheres and a temperature of approximately 250° C. The compressed and heated air is supplied to a heat exchanger **2**, wherein it undergoes heat exchange with the exhaust gas from a turbine **5**, and the temperature of the air is raised to about 350° C., and delivered to a combustion chamber **3**. Preheated hydrocarbon fuel is continuously injected into the combustion furnace in an amount corresponding to that of the compressed air for complete combustion of the fuel. Combustion is effected at a temperature of about 1500° C. in chamber **3**. The high temperature and pressure combustion gas thus formed in combustion chamber **3** is led to a cracking furnace **4**. Superheated steam and naphtha are introduced in furnace **4** in prescribed amounts to cause thermal cracking of the naphtha which has been preheated to about 200° C. and which is injected into the furnace. The quantity of naphtha introduced into furnace **4** is such that the temperature of the gas mixture is regulated to about 700 to 800° C. Then, the gas mixture is delivered to gas turbine **5**, wherein energy of the gas is delivered to the turbine to drive the same while the gas experiences a reduction in pressure and cooling and is discharged at atmospheric pressure at a temperature of 400 to 450° C. The gas, after being cooled by heat exchange in the heat exchanger **2** is subjected to further utilization of the waste heat (not shown) and is then transferred to well known gas purification and separation means **6**.

According to the said method, energy balance for a 23,600 kg./hr. naphtha cracking plant, requires that the output of the turbine be about 7600 kw., the required power for compression of the air being about 2300 kw. The gas turbine generator terminal efficiency is 15.6% and the overall thermal efficiency of plant is about 79%.

Actual operative conditions are shown as follows:

(1) Air:
   before compression, 36,400 kg./hr., 1.033 atmospheres, 15° C.
   after compression, 36,400 kg./hr., 6.3 atmospheres, 239° C.
   after heat exchange, 36,400 kg./hr., 6.3 atmospheres, 350° C.

(2) Fuel, 2,450 kg./hr., 200° C.

(3) Combustion temperature, 1,500° C.

(4) Steam quantity, 3,450 kg./hr., 276° C.

(5) Heavy naphtha (raw material), 23,600 kg./hr., at 200° C.

(6) Cracked gas
   Before turbine charging, 65,900 kg./hr., 6 atmospheres, at 750° C.
   After turbine exhaust, 65,900 kg./hr. 1.08 atmospheres, at 432° C.
   After heat exchange, 65,900 kg./hr., 1.08 atmospheres, at 383° C.

(7) Product yield (wt. percent):
   Ethylene: 29, propylene: 10, methane: 32, butane: 1, Hydrogen: 15, ethane: 7, propane: 1, butadiene: 2, butylene: 3

The present invention is of course applicable and practicable not only to the use of a gas turbine and naphtha, but also to combinations of any apparatus for generating power through adiabatic expansion as well as any kind of hydrocarbon product. Apparatus suitable for adiabatic expansion, may be gas turbines, reciprocating engines, screw-type gas expansion apparatus, gear-type gas expansion apparatus, Roots-type gas expansion apparatus and the like. On the other hand, such apparatus, which injects the high temperature and pressure gas by means of nozzles, are widely applicable and practicable without giving introducing serious difficulty.

What is claimed is:

1. A method of driving a gas turbine while cracking naphtha, said method comprising compressing an oxygen containing gas in a compressor, mixing the compressed gas and a hydrocarbon fuel in a combustion chamber and effecting complete combustion of the fuel in said chamber to produce a combustion gas at a temperature of between 1300 and 1500° C., mixing said combustion gas with a mixture of naphtha and superheated steam in a cracking furnace to crack the naphtha, the naphtha and superheated steam being added to the combustion gas in a quantity and a pressure such that the temperature of the thus obtained gas mixture is between 700 and 800° C., adiabatically expanding the latter gas mixture in a turbine to drive the same while rapidly cooling the gas mixture to prevent polymerization thereof, cooling and thereafter separating the cracked constituents of the naphtha from the gas mixture after the latter has been discharged from the turbine, and driving said compressor by said turbine.

2. A method as claimed in claim **1** wherein the oxygen containing gas is brought into heat exchange relationship with gaseous mixture discharged from the turbine prior to said combustion.

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