Title: METHOD OF AND INSTALLATION FOR ELECTRICAL POWER GENERATION

Abstract: In a method of and installation for generating electricity from oil-bearing plant material, the residue plant material after oil extraction is comminuted and combined with oil, which may be recovered vegetable oil, the extracted oil, or a mixture thereof, for use in fueling a gas turbine engine driving an electricity generator.
Description

METHOD OF AND INSTALLATION FOR ELECTRICAL POWER GENERATION

Technical field

[0001] This invention relates to a method of, and an installation for, generating electrical power from oil-bearing plant material.

Background art

[0002] Since fossil fuel reserves are limited and there are considerable doubts over the long-, and indeed short-, term safety and economic viability of nuclear power generation, the use of renewable sources of energy is increasingly desirable. While wind and tide can provide a certain amount of electrical power, it can only be a limited part of any nation’s needs, and so other sources of renewable energy are very important. Vegetable oil is an example of a renewable fuel. When vegetable oil is used as a fuel, replacement crops can be grown and more vegetable oil produced. This cycle can go on endlessly as long as there is good land on which to grow crops. As long as we take care of our land, renewable fuels will never run out.

[0003] Vegetable oils can be extracted from the seeds of a range of different plants, most notably oil-seed rape, which is widely grown in the EU. Fuel oils derived from vegetable oil, commonly referred to as “bio-fuel”, have been shown to be a satisfactory substitute for petroleum-derived fuels, with calorific values approaching those of petroleum-derived fuels, but with a significantly lower environmental impact, since less pollution results from their manufacture and use.

[0004] However, a significant by-product of the production of vegetable oil is the solid material or “cake” from which the oil has been pressed. Conventionally, this is used in animal feed, but increasing the production of oil to fuel electricity generating stations would result in an over-production of cake, in excess of that currently required for animal feed purposes. This could have an adverse effect on the animal feed market, or simply result in the need to dispose of the solids as waste, adding to the cost of electricity generation. In addition, the vegetable oil typically
comprises some 40% of the total weight of the seed. The remaining 60% is residual cake which by mass calorific value equates to some 45% of the total energy value. In energy terms, disposing of the residual cake is inefficient.

[0005] In addition, to increase overall efficiency of power generation from vegetable-derived fuels, it is desirable to reduce transport costs by processing the vegetable material and then generating the electricity as near as possible to where the material is grown, rather than centralising processing and generation in locations remote from the area of production.

Disclosure of the invention

[0006] It has now been found that by comminuting the solid cake and mixing it with the refined fuel oil, a modified fuel oil is produced which can not only be burnt in a conventional furnace, but can also be used as a fuel for a gas turbine engine, permitting the construction of small-scale, highly-efficient electricity generating stations to produce electricity where the oil-bearing plants are grown.

[0007] Accordingly, the invention provides a method of generating electrical power from oil-bearing plant material, comprising:

[0008] pressing the plant material to extract oil therefrom leaving waste plant material;

[0009] comminuting at least some of the waste plant material and mixing the comminuted material with oil; and

[0010] burning the mixture of comminuted material and oil in an engine to power an electrical generator.

[0011] The invention also provides an installation for generating electrical power from oil-bearing plant material, comprising:

[0012] a press for pressing the plant material to extract oil therefrom leaving waste plant material;

[0013] a mill for comminuting the waste plant material;

[0014] mixing means for mixing the comminuted material with fuel oil; and

[0015] an engine arranged to burn the mixed fuel oil and comminuted material to power an electrical generator.
A considerable market exists for recovered vegetable oil (RVO) from the waste cooking oil of commercial establishments. This oil has been used consistently for animal feed processes, but current legislation will shortly prevent this use. RVO can and has been successfully processed to make Bio-fuel. Preferably, at least a portion of the oil with which the comminuted material is mixed is RVO. The recovered waste oil is preferably refined, either before or after mixing with the comminuted waste plant material.

The extracted oil may undergo a refining process to produce a refined fuel oil, which may be used in the engine powering the electrical generator or may be sold, for example as a fuel for diesel-engine road vehicles.

The refining stage suitably includes an esterification process to produce a refined fuel oil and glycerol. Production of methyl esters is preferred, for example reacting the oil with methanol and sodium hydroxide.

Since the refining process, and in particular the esterification of the oil, produces fuel oil at an elevated temperature, it is preferred to pass the fuel oil through a heat exchanger to pre-heat the extracted oil (and, where used, recovered oil) entering the refining step. The heat exchanger preferably is preferably of the general type described in US 6 282 917, having heat pipes to improve heat transfer efficiency.

It has been found that the fuel produced in accordance with the invention can be used in gas turbine engines with relatively minor modification to the burners. Preferably, the gas turbine engine is provided with two burners, a first supplied with the fuel oil produced by the refining stage (referred to as "Grade 1"), and the second with fuel oil containing the comminuted waste material mixed in (referred to as "Grade 2"). Thus, for example, the turbine can be started using the Grade 1 fuel and then Grade 2 fuel can replace at least a part of the engine's fuel requirement, via the second burner. Preferably, the first burner is positioned slightly in front (downstream) of the second burner.

Preferably, the gas turbine engine is provided with a heat exchanger to transfer thermal energy from the exhaust gases from the turbine to the compressed air leaving the compressor stage of the turbine, thereby reducing primary fuel use. This heat exchanger may involve the use of
heat pipes to improve heat transfer efficiency. It is also desirable to cool the air entering the turbine engine air intake to improve volumetric efficiency, and a chiller may be provided for this purpose.

Brief description of the drawings

[0022] In the drawings, which illustrate exemplary embodiments of the invention:

[0023] Figure 1 is a schematic view of an installation according to the invention; and

[0024] Figure 2 is a perspective view of a gas turbine engine/generator unit for use in the installation of the invention.

Mode(s) for carrying out the invention

[0025] Referring to Figure 1, the installation comprises a receiving hopper 1 into which the harvested oil seeds are delivered from neighbouring farms. From the hopper 1, the oil seed is passed to a screw press 2, which has a helical screw with its shaft diameter increasing in the direction of the material flow to ensure a mulching compressing effect. The crude vegetable oil is delivered under pressure through a perforated plate to the oil outlet. This oil comprises some 40% of the total weight of the seed. The remaining 60% is residual cake which by mass calorific value equates to some 45% of the total energy value.

[0026] The crude vegetable oil passes to a holding tank 3, alongside which are conveniently located storage tanks for recovered waste oil 4 and prime fuel 5, as well as alcohol 6. The recovered waste oil is vegetable oil recovered from commercial cooking establishments, and is used in the processing of the residual cake, as hereinafter described. The prime fuel tank 5 is optionally provided to store back-up fuel to guarantee electricity output, even if vegetable oil were not available. The alcohol tank 6 holds process alcohol (ethanol or, preferably, methanol) for use in the trans-esterification process as hereinafter described.

[0027] The trans-esterification process is carried out in a series of batch reactors 7. Vegetable oils are triglycerides, and esterification with alcohol breaks down the glyceride molecules to yield three methyl ester molecules and glycerol. The resulting ester is of lower viscosity and higher calorific value than the crude oil. Ethanol is typically produced industrially by

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fermentation, usually of grains, while methanol can be made from coal, natural gas or wood. It has been found that methanol produces a more stable bio-fuel reaction because it is less affected by water content in the oil than ethanol, but has the disadvantage of being toxic and more difficult to handle (for example, it tends to dissolve rubber).

[0028] The esterification reaction requires the presence of sodium hydroxide or potassium hydroxide as a catalyst. Typically, the hydroxide is mixed with the methanol before being pumped into the reaction vessel 7 to be mixed in turn with the crude vegetable oil (and recovered vegetable oil, where used). The reaction vessels or batch reactors 7 each contain a mixing paddle and a heating coil to maintain a reaction temperature of about 50°C. The glycerol produced in the reaction settles to the bottom of the vessel 7. 75% of the reaction takes place in the first hour, but a period of four to six hours is typically required to bring the reaction to completion. The glycerol and entrained hydroxide is drained off from the bottom of the vessel for further separation to produce refined glycerol to be stored in a storage tank 8 for subsequent use or sale.

[0029] The first reaction vessel 7 is now full of Bio-Fuel at a temperature of circa 50°C. Alongside is an identical pair of tanks, the reaction vessel Number Two full of CVO at an ambient temperature of circa 15°C. A heat exchanger 9 is used to transfer energy from tank one to tank two. The heat exchanger may incorporate heat pipes to assist in heat transfer, for example as disclosed in US 6 282 917. The resulting cooled Grade 1 fuel is pumped to fuel storage tanks 10.

[0030] The residual cake from the screw press 2 is passed to a blending hammer mill 11 to be pulverised into a very fine particulate form. To assist the shearing or reduction recovered vegetable oil is added to achieve the correct consistency and, under a certain temperature profile, the correct viscosity to be achieved. The blend of comminuted waste solids and recovered waste vegetable oil produces a Grade 2 oil having a calorific value approximately 78% that of the Grade 1 fuel. The oil is preferably also subjected to a trans-esterification process, either before or after mixing in of the comminuted solids. Up to about 55% by weight of the

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Grade 2 fuel may be provided by the comminuted waste cake from the hammer mill 11.

[0031] The fuel is supplied to a gas turbine engine 12, for example as hereinafter described with reference to Figure 2, driving a generator to supply power to the grid 13 via an interface controller and transformer 14.

[0032] Referring now to Figure 2, in the gas turbine 12 air is drawn into the intake 21 through a rotating impeller which together with a ring of static vanes, forms the compressor sections of the machine. As the air is passed through the compressor it is accelerated outwards at high speed and then slowed down again in a ring of static guide vanes. The air at this stage is getting warmer due to the compression. At this point prior to the combustion chamber, the air passes through a heat exchanger 22 which comprises a plurality of heat pipes transferring thermal energy from the turbine exhaust gases at a temperature of circa 570 degrees C. The heat exchanger receives the heat from the exhaust gas stream and pre-heats the inlet air, lifting it from 40 degrees C to 410 degrees C entirely from waste. The combustion chamber now has only partial work to do in that it is not lifting the gas from 40 C to 1000 C but, due to pre-heating, from 410 C to 1000 C, thus saving considerable amounts of primary fuel.

[0033] In the combustion chamber 23 the engine comprises an array of twin burner arrangements firing into a swirl chamber. The Grade 1 fuel will fire through a standard traditional pressure burner. This Grade 1 fuel performs in every way the same as a light fuel oil. The secondary burner is modified to accept Grade 2 fuel. Due to the consistency and viscosity variation the atomising configuration is slightly different. However by positioning the first burner slightly in front of the secondary burner, complete combustion takes place in the swirl chamber.

[0034] The hot gases generated by the combustion process drive a series of turbine wheels configured in an axial flow format. The expanding gases create mechanical power. This power drives the compressor part of the machine and also the power production part, the generator. The temperature in the combustion chamber is in the order of 1000 degrees C and at the exit, after doing the work, is reduced to 570 degrees C. By
directing the exhaust gas over the heat exchanger we achieve the pre-
heat thus reducing primary fuel use.

[0035] In order further to improve engine efficiency, a chilling coil 24 is located in
the air intake 21 to the engine, since cooler air entering the compressor will
be denser than warmer air. The cooling water for the chilling coil 24 is
produced using an absorption chiller 25 driven from the residual heat of
the exhaust gases from the turbine, by way of a further heat exchanger in
the exhaust outlet heating circulating water.
Claims

1. A method of generating electrical power from oil-bearing plant material, comprising: pressing the plant material to extract oil therefrom leaving waste plant material; comminuting at least some of the waste plant material and mixing the comminuted material with oil; and burning the mixture of comminuted material and oil in an engine to power an electrical generator.

2. A method according to Claim 1, wherein at least a portion of the oil with which the comminuted material is mixed is recovered waste vegetable oil.

3. A method according to Claim 2, comprising refining the recovered waste oil to produce a refined fuel oil before mixing in the comminuted waste plant material.

4. A method according to Claim 1 or 2, comprising refining the mixed oil and waste plant material.

5. A method according to any preceding claim, comprising refining the extracted oil to produce a refined fuel oil.

6. A method according to Claim 3, 4 or 5, wherein the refining step comprises subjecting the oil to an esterification process to produce a refined oil and glycerol, and separating the refined oil from the glycerol.

7. A method according to Claim 6, wherein the esterification process comprises treatment of the oil with methanol.

8. A method according to any preceding claim, comprising passing the fuel oil from the refining step through a heat exchanger to extract heat from the fuel oil and to increase the temperature of the oil entering the refining stage.

9. A method according to Claim 5, comprising using a heat exchanger comprising a plurality of heat pipes.

10. A method according to any preceding claim, wherein the engine is a gas turbine engine.

11. An installation for generating electrical power from oil-bearing plant material, comprising: a press for pressing the plant material to extract oil therefrom leaving waste plant material; a mill for comminuting the waste plant material; mixing means for mixing the comminuted material with fuel oil; and an engine.

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arranged to burn the mixed fuel oil and comminuted material to power an electrical generator.

12. An installation according to Claim 11, comprising processing means for refining the fuel oil, or the mixed fuel oil and comminuted material.

13. An installation according to Claim 11 or 12, comprising processing means for refining the extracted oil to produce a refined fuel oil.

14. An installation according to Claim 12 or 13, wherein the processing means includes a reaction vessel for carrying out an esterification process on the oil.

15. An installation according to Claim 14, wherein the processing means comprises a heat exchanger to transfer heat from the fuel oil produced thereby to the extracted oil entering the processing means.

16. An installation according to Claim 15, wherein the heat exchanger comprises a plurality of heat pipes.

17. An installation according to any of Claims 11 to 16, wherein the engine is a gas turbine engine.

18. An installation according to Claim 17, comprising a heat exchanger associated with the gas turbine engine to transfer heat from the exhaust gases to air entering the engine.

19. An installation according to any of Claims 11 to 18, wherein the mill is a high-speed hammer mill.
# INTERNATIONAL SEARCH REPORT

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC 7 C11B1/06 C11B13/00 C11C3/00 C10L5/44 F01K25/00

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C11B C11C C10L F01K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, FSTA, BIOSIS

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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- Special categories of cited documents:
  - "A" document defining the general state of the art which is not considered to be of particular relevance
  - "E" earlier document but published on or after the international filing date
  - "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specificed)
  - "O" document referring to an oral disclosure, use, exhibition or other reason
  - "P" document published prior to the international filing date but later than the priority date claimed

**Further documents are listed in the continuation of box C.**

**Patent family members are listed in annex.**

**Date of the actual completion of the international search**

14 September 2005

**Date of mailing of the international search report**

05/10/2005

**Name and mailing address of the ISA**

European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, TX. 31 651 epo nl Fax (+31-70) 340-3018

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