1. Surname, name

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2. Denomination

Efficiency of turbine power plants when using steam and gas working fluid
and high temperature regeneration

3. Specialty

05.14.06. – Engineering thermophysics and industrial power

4. Employer

Europa Maritime Odessa Co. Ltd.

5. Dissertation research effected at

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Author has analyzed methods of increasing efficiency of steam turbine, gas turbine and combined cycle power plants by introducing changes in thermodynamic cycles. It is supposed to use existing technologies for manufacturing plants' units (such as turbines, boilers, combustion chambers).

For a steam turbine plant it is proposed to increase the average temperature of the heat supply (and consequently efficiency). In the first case this is achieved by mixing superheated steam with products of combustion such as natural gases in oxygen on high temperatures parts of the isobaric processes of initial and intermediate superheating of steam. Superheated steam, which is produced in the boiler, then proceeds to a combustion chamber where it is mixed with products of combustion of methane in oxygen. Working substance with parameters 24 MPa and 1,430 oC is expanding in high pressure turbines to pressure 3.6 MPa. Then it proceeds to a second combustion chamber where the working substance is again heated up to 1,430 oC. Thermal efficiency of the cycle is increased by 24.8 % (from 53.3 % to 66.5 %), and effective efficiency by 22.4 % (from 47.4 % to 58.0 %).

In the second case average temperatures of heat supply is increased by maintaining steam temperature during the major parts of expansion in the turbines close to its initial values. Heat is supplied to the working substance during expansion. The temperature is maintained by multi stage combustion of fuel in the stream of the working substance during its expansion in the turbine. Steam after the boiler with a temperature of 540 oC is then mixed with the products of combustion such as methane and oxygen and excess of methane. The quantity of these products is determined by the temperature of the working substance after the combustion chamber which is equal to 1,430 oC. Excess of methane is then determined by the quantity of heat which should be supplied during expansion. Oxygen is also gradually added to the working substance for combustion of the methane during expansion in turbines. Effective efficiency is increased by 20.1 % in comparison with the combined cycle plant (from 60.0 % to 72.1 %). In order to achieve a lower temperature of the working substance at condenser's inlet it is necessary in both cases to introduce a regenerative heat exchange by feeding water to the working substance after its expansion to atmospheric pressure. After a regenerative heat exchange the working substance then expands in a low pressure turbine to the condensation pressure.

For a gas turbine plant it is proposed to introduce regenerative heat exchange between air and gas after its expansion in a high pressure turbine and before the entering of gas into a low pressure turbine. This yield increases the air temperature at the combustion chamber inlet which then respectively increases the average temperature of heat supply. Such a high temperature regenerative heat exchange will also reduce average temperature of heat extraction because the temperature of the gas after a low pressure turbine will be lower than its temperature after regenerative heat exchanger in a traditional cycle. For a gas turbine plant with a temperature of gas at a high pressure turbine inlet of 1,430 oC, the increase of thermal efficiency is 20.9 % (from 59.2 to 71.6 %) and effective efficiency– 12.8 % (from 43.6 to 49.2 %).

For combined cycle plants new method of steam generation has been proposed. If heat transfer from gas to moist steam is excluded from the cycle and heat transfer only takes place from gas to liquid and from gas to superheated steam, losses from irreversibility of heat transfer will be reduced. Steam will be generated during multi stage throttling from supercritical pressures and near critical temperatures to pressure which will slightly exceed condensation pressure. Throttling of liquids and further separation of moist steam on saturated liquid and saturated steam do not require complex devices. For this reason number of throttling stages can be more than number of steam generation stages in traditional combined cycle plants. Such increases in the number of steam generation stages will not make plants more complex but it will reduce losses from internal irreversibility of the cycle. Increase of effective efficiency of the steam part of the plant is 4.1 % (from 31.5 % to 32.8 %) and effective efficiency of combined cycle plant is 1.0 % (from 57.2 % to 57.8 %). Plants with multi throttling stages will be less complex than traditional plants so the introduction of the method on new plants will reduce construction costs. The capital recovery period will be determined by expenses on R&D and rearrangement of the manufacturing process.

Keywords: efficiency of power plants, effective efficiency, steam turbine plant, gas turbine plant, combined cycle plant, thermodynamic cycle.