APPLICATION OF WASTE HEAT FROM THE ENGINE COMPRESSOR STATION

Marián Hocko - Peter Fedor

The article is about the design project of recovering waste heat from the engine who´s turbosupercharged three gas compressor station in Veľké Kapušany. The article analyzies need and the current trend of using alternative energy sources. Devoted the analysis of combustion turbine compressors used for the transportation natural gas and description used in the combustion turbine compressor station in Veľké Kapušany. Points to the possibility of using waste heat output gas combustion turbine compressor station. It also deals with design combined cycle compressor station in Veľké Kapušany. Post refers to the proposal of using waste heat from the engine compressor station, showing the size of the energy, which can be further used in the heat exchanger to produce steam. Steam can then be used to drive the turbine power generator.

K ey wo rds: combustion turbine, combined cycle, waste heat boiler flue gas exchanger.

1 INTRODUCTION

We live in period when the question of power becomes a problem in terms of resources. Energy demand that arises is mainly due to population growth, dwindling fossil fuel reserves, it also can be seen in a small progress in the development, new alternative energy sources and many other factors. Several factors pose a threat as was recently the nuclear power plant accident in Fukushima, which had a great impact on the environment. In Germany, the trend occurs decommissioning of nuclear power plants and switch to using renewable energy such as biogas plants, wind power plants use steam-gas cycles, etc.

Currently coming to the foreefront is renewable energy. These resources are of interest for its environmental friendliness and global preference. One of the other possibilities of increasing production of electricity and thermal energy, venture into the field of increasing the efficiency of steam and steam cycles. The main objective should be to increase efficiencies that can be achieved by improving technology savings coal, biomass, liquid fuels and natural gas to produce electricity and thermal energy.
Currently - Slovak republic is the production and consumption of electricity provided to about 2,5% of balance, it means that the import volume was slightly higher than export electricity abroad.

As expected electricity demand will grow in Slovakia. At the Slovak market have a dominant position in the electricity generation nuclear power plants, thermal power and hydropower. To a lesser extent in Slovakia electricity supply wind power, solar power. Achieve one of the main objectives of energy policy, which is to ensure that the volume of electricity that demand will be covered only by ensuring sufficient productive resources to produce it. Realize that the main objective of energy policy can be:

- Increasing enforcement of existing production facilities,
- construction of new production facilities.

The total consumption of electricity in our country produces 5,2 TWh by renewable sources, representing 16% of total energy consumed. Outlook for 2020 is 24% of the total electricity consumed.

Renewable huge potential of our country, but their actual use as an energy source is at least the possibility.

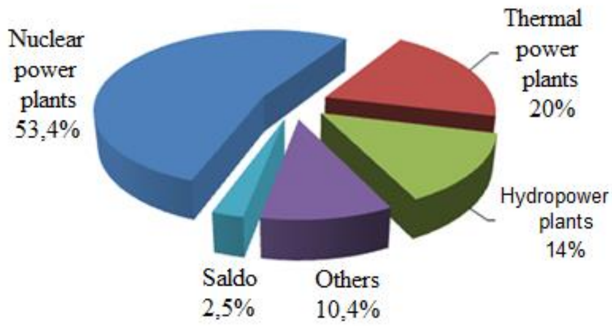

Figure 1 Proportion of funds to cover the annual consumption

One of renewable energy sources is a combined cycle which opens the door to the possibility of increasing efficiency, because it represents the connection of the steam-gas cycle. Currently, gas turbine reaches an average value of 35% (max. 40%) and combined steam-gas mode can reach values up to 57% efficiency. Combined cycle operates on the principle of a combined circulation where such use multiple input heat contained in the fuel is better utilized and energy input into the combined cycle, with lower exhaust emissions that also play one of the essential tasks nowadays.

When transporting natural gas combustion turbines are used to drive the compressor compressing the gas, and thus secure transmission of natural gas.

Used in the combustion turbine compressor station were developed from aerial turbosupercharged engines and work on the same principle. However, for aircraft engines can´t be any more waste heat than it is for gas turbines. The operation of these turbines is in most cases continued 24 hours a day. As the operation of three combustion turbines Rolls-Royce RB 211 in the compressor station Kapusany large amount of waste heat is enormous and has great potential. During this time it is not utilized this heat, although it is possible to output the heat of combustion turbines further use. For example, in electricity generation combined cycle turbine, greenhouse heating or domestic hot water for heating buildings.

2 COMBUSTIONTURBINESINPIPELINES

The extraction of natural gas is one of the major problems of seasonal difference of gas supply; effort that is, the use of divorce pipeline system was as evenly as possible. For this, use natural reservoirs. They are underground pressure reservoirs in which gas is pumped by special compressor units, which operate at high pressure levels with compression ratio π_{kc} = 2 to 5 The transmission network used pressure levels lower, such as compressor station Veľké Kapušany is π_{kc} compression ratio = 1,5.

Substantially more significant area is the transportation of natural gas by pipeline. Combustion turbines are applied in this area precisely because, unlike electrically powered reciprocating engines or compressors for gas turbines is easier speed control. The investment, operating and maintenance regard proved to be best compared to piston engine. More and more horsepower combustion turbines that are developed primarily for the propulsion gas pipeline compressor stations, allows you to zoom performance of the transport system over the possibility of other kinds of power.

2.1 Gas Turbine ROLLS-ROYCE RB 211 DLE

The Rolls-Royce company, in the development of gas turbine systems, dominates mainly due to its experience in international projects, which have played a key role, particularly because of its reliability. Achieve the highest performance and relatively easy to maintain systems of gas turbines RB 211 Systems provide ideal solutions for today's tasks, which can increase the efficiency of the exhaust heat recovery for hot steam or hot water heating and subsequent heating.

Application pipelines to secure just by working with highly efficient and simple cycles. RB211 is suitable to drive pipeline compressors and pumps. It has low weight and the ability to quickly remedied thanks to the excellent correction granted by Rolls-Royce is a key element in the transmission of natural gas. This advantage is important because the pipeline facilities are located in remote areas far from maintenance service points. That is why the RB211 demand in transportation of natural gas, following the trend in the field of gas.

Gas generator RB 211 DLE is dvojrotorový turbo engine with high pressing, which has a seven-speed six-speed medium-pressure compressor and high pressure compressor. Each rotor is driven by a separate single-stage turbine. The two rotors are mechanically independent and run with its own optimal speed. Industrial RB211 are derived from the design of aircraft engines used on Boeing 747, 757, 767 and Tupolev Tu-204.

Part of the gas generator combustion system with dry low emissions, which resulted in the designation of DLE. Philosophy of combustion chamber with low emissions is based on the current limitation of emissions of NOx (oxides of nitrogen) and CO (carbon monoxide). To achieve the desired result, it uses a step-burning of lean, pre-mixed fuel in several stages. The lean-burn system allows you to control the combustion temperature within the required range without interruption burning.

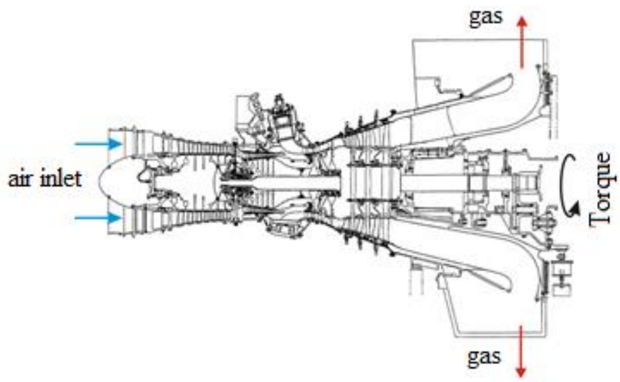

Figure 2 Cut the engine RB211 DLE

3 APPLICATIONOFWASTEHEATFROMTHE ENGINECOMPRESSORSTATION

When the possibility of using waste heat from the gas compressor station is a use of gas from the gas turbine, whose main function is to propel gas compressor. The compressor provides the necessary pressure pipeline natural gas for transportation in transit pipelines. This residual heat gases offers potential for further use. It is the inclusion of waste heat boiler to off-gas stream, which uses thermodynamic cycles - these are well chosen thermodynamic processes which build on each other and thus form a closed circulation heat. The entire cycle after their racing returns to its initial state. The most commonly used method converts thermal energy, ie combustion of solid or liquid fuels, the use of the steam cycle, which is known as the Rankine - Claus cycle. Its essence is the water heater and its further transformation to the high pressure steam, which is fed into a steam turbine where it expands.

In this way, part of the energy is transferred to the steam engine (turbine) and acting work.

One option to be used resulting mechanical energy to the turbine blades is to use it to drive an electric generator. This option is the most economically effective because of the fact that electric energy will thus produced can serve as the captive compressor station. If the amount of electricity generated is higher than necessary consumption of the compressor station may be the electricity distributed to the electrification network. Thus enhancing the efficiency of the whole system.

Another option is to use waste heat to power CHP. It is a domestic hot water, which can serve as building heating in the winter months, or as heating greenhouses.

However, as the most suitable solution is electricity production and subsequent distribution. A similar principle as for the combined cycle power plant with the only difference that the main function of the

system is designed to drive gas pipeline and electricity production is secondary.
In practice, they are mainly used thesesolutions:

- heating,
- domestic hotwater,
- technological purposes,
- cooling,
- electricity consumption:
- Primarilyfor their own consumption,
- Supply to the publicelectricitygrid.

3.1 Principle combined cycle

The principle technical performance and show the T - s diagram is shown in Fig 3. Working fluid, which is air, is sucked in (5) and compressed by the compressor motor BY RB 211 and then fed into the combustion chamber (6), in which fuels are oxidised (7) (natural gas). Fuel passes through the gas turbine, which sells the expansion of their energy (8). Fuel gases from the gas turbine are continuing into the boiler, where out a gas and steam cycle. The boilers heat transfer occurs combustion (8-9) water and there is the development of a heating steam in the steam cycle (2-3). Part of the heat that is not used leaving (9-5), which means that we are creating a flue loss. Steam boiler is designed like a boiler arc power. In some cases, technical designs and enables the boiler heating or reheating of water - vapor steam circulation heat source independent of the gas stream. Superheated steam is expanded further through the steam turbine and residual heat goes through the exchanger.

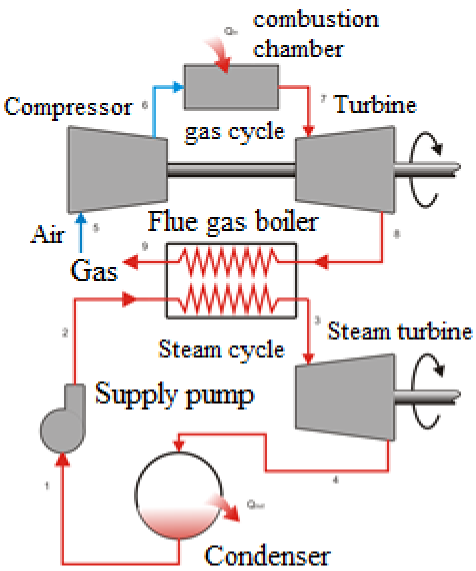

Figure 3 Combined Cycle Power

Installation of cogeneration technologies in a business, property or service is appropriate and cost-effective when on-site met certain essential conditions, which is actually a non-stop uninterrupted operation of this technology. Annual operational use should be a minimum of 6 000 hours. While the focus is primarily on the effective use of heat from cogeneration. Electricity has to be used primarily for their own consumption keeper's electrical appliances, any excess power can be supplied to the public electricity grid.

At Ts diagram in Figure 4 are drawn comparison circuits of both turbines. The chart shows that the outlet temperature of flue gas turbine (point 8) is high enough to be able to generate superheated steam in waste heat boilers (section 3).

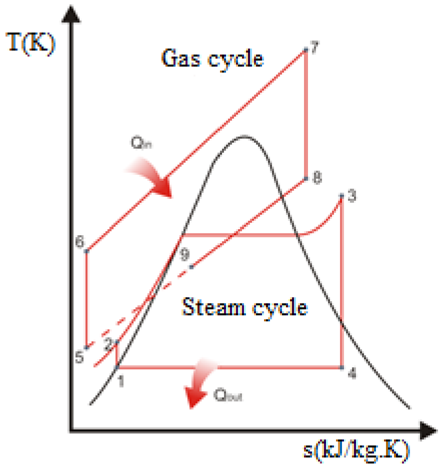

Figure 4 T-s diagram CCGT

3.2 Advantages of combined cycle

- modulardesignallows you to changeoutput parameters, whichcan change over time,
- shortrise time(a few hours from cold,
- installation in about12 to 20 months whilecoal-fired power plants3-4 years,
- advances in the technology of gas turbines and cooling system improves the overall efficiency of the system which achieves nearly60%,
- NO_x and CO emissions are very low(use qualityfuels),
- possibilityof performances in thousands ofMW(previously available only in the design of conventional coal and nuclear power plants). [1]

3.3 Disadvantages combined cycle

The main disadvantage is based on the combustion turbine output temperature. With warmer atmospheric air reduces its density and reduces air flow turbine (power turbine is dependent on the mass flow rather than volume). This reduces the amount of exhaust gas from the gas turbine, entering the waste heat boiler, where it is bound to produce less steam for the steam turbine (steam or other need). Ambient temperature has a negative impact on the consumption of heat (heat rate) and flue gas temperature. Unfortunately, the hot summer weather also corresponds to an annual peak electrical load (air conditioning and other cooling devices) in many areas of the world. Therefore, the solution to this "summer problem" is most often used these three methods.

– cooling inlet air to the compressor inlet,
– steam injection into the combustion turbine,
supporting burners in waste heat boilers.

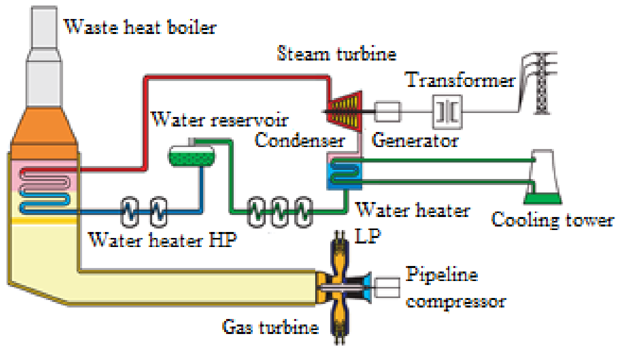

Figure 5 Schematic representation of a combined cycle

4 MOTION WASTE HEAT FROM THE ENGINE COMPRESSOR STATION

As a basis for design use waste heat engine we used RR RB 211 DLE. The approximate thermodynamic calculation can determine the approximate useful heat contained in the flue gas, which can still be used in that steam cycle. The following table is calculated usable heat exhaust and its approximate mean value.

Table 1 Useful heatcontainedin the flue gas

The flue gas temperatureat the outletofthe powerturbine(values calculated) [°C]	Useful heat cp . ΔT
461,88	487099,2
462,199	487446,91
462,199	487446,91
461,56	486750,4
467,632	493368,88
467,286	492991,74
456,497	481231,73
456,1838	480890,342
median	487142,4512

The table shows us that for the steam cycle is available on value of useful heat Qvýs. Heat 503 = 492.45 [J. kg-1]. In our case, when they are available in three compressor station gas turbines RB 211, which were using the waste heat, so you can utilize the full potential value of Qvýs. Heat 477.4 = 1510 [J kg-1].

4.1 Proposed combined cycle

As a major source are three gas turbine-type RB 211, whose main function is to transport natural gas as shown in Fig. 2. Their by-product of the waste heat (combustion). Flue gas is currently vented to the atmosphere. My suggestion would be to use the gas from the gas turbine to generate electricity using a steam turbine. Due to export (sale) of electricity must be ensured constant supply to the public electricity grid. This condition could be satisfied by the production of electricity would serve only two combustion gas turbines RB 211 and one gas turbine would serve as a backup in case of a breakdown or other emergency situation. Alternatively, the waste heat boiler may be different in that it would be used in the first case as a back-up for the production of steam for the steam turbine, in the latter case, it performs the functions of heating hot water network, because in order to use from an environmental perspective as many waste heat.

As the first adjustment is necessary chimney into which you need to install the damper to serve the combined operation. In the first case would serve as a guideline flue gas stream to the atmosphere and in the latter case would serve as a guideline to the current gas waste heat boiler. The case, which would serve to divert gas chimney into the atmosphere from the ground to increase the flexibility of the cogeneration unit (speed combustion turbine start-up requirements for the main function, gas transmission, which is not limited to the boiler flow). It would be appropriate to use a bypass stack.

Furthermore, the system is assigned to each one a separate turbine waste heat boiler. There could be a boiler with reheating to better use and stabilize the electrical output voltage. Due to the fact that the off-gas reheating in the order of 80 to 120 °C. We will increase the overall performance and stabilization output electric voltage with no large supply additional fuel into the system.

Steam-water pipe waste heat boiler steam would be moved to a steam collector and from then fed into one pipe condensing steam turbine. It is important to pay attention to the fact that in the area there are gas pipelines and must comply buffer zones around them.

When choosing a steam turbine should be based on the fact that during the winter months could take steam which could be used for heating. When such use shall be operated in a wide range of fully condensing mode, which does not transmit any turbine steam (no heat for other purposes), up to a maximum offtake arrangements. To this end, I chose condensing type turbine.

The system for a steam turbine is still the possibility to include heating network water through the heat exchanger station (steam/water mains). Steam, which is drained from the steam turbine is still the possibility to use it in the above substation for heating water.

We must not forget to remove the large amount of heat contained in the steam that rises from the steam turbine, the activity is carried out in the condensation system.

For each gas-steam system must be an adequate amount of water for its operation. This water must meet certain criteria. To prepare the water tank must be provided with the necessary degasser with prescribed volume and steam output. The degasser removes the water vapor thermally own the nominal pressure and temperature, O_2 and CO_2 emissions, thereby also heated to the desired temperature required to heat exchanger. The pH (if necessary) is added a solution of NH 4 OH.

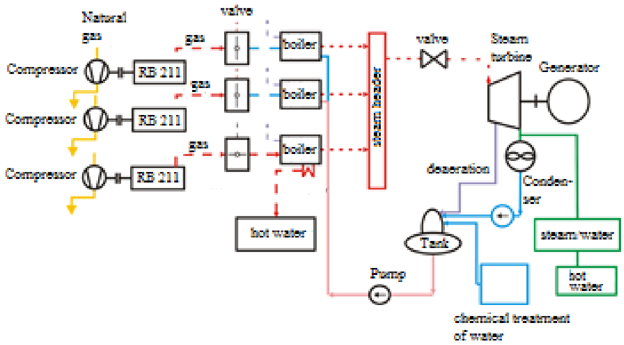

Figure 5 Schematic of the proposed CCGT system

5 CONCLUSION

The proposal for dealing with the possibility to further utilize waste heat from the engine compressor station was a selected combined cycle, which is currently the most efficient and most environmentally friendly energy sources. Energy efficiency combined cycle power sources is based on the use of chemical energy of fuel (natural gas) in the two successive thermal cycles and Brayton cycle combustion turbine and Clausius - Rankine steam cycle. The cycle is proposed for the production of electricity and partial heating hot water. Due to the electricity supply guaranteed minimum level, it was proposed to use two gas turbines as the main source for the production of steam and gas turbine one as a backup for emergencies. Other components such as waste heat boiler, gas turbine and chemical treatment of water are designed in theory. The design of a complete steam cycle could be filling further work.

From the balance sheet perspective chosen by the use of waste heat for electricity generation in place was the size of about 130 to 150 GWh and 20 to 22 GWh of thermal energy per year. In today's electricity prices for households amounted to the sum of the amount of energy produced from 9.5 to 10,900,000 euros per year and 1.25 to 1,370,000 euros for the sale of thermal energy. Presented proposal is a saving of fossil fuels, which is a considerable benefit to the environment. Project implementation should return for a small initial investment and create more development assumptions compressor station.

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