František LUDVÍK

CIVILIAN APPLICATION OF LIQUID PROPELLANT ROCKET MOTOR PRINCIPLE

Reviewer: Jan KUSÁK

A b s t r a c t :

The paper deals with application of liquid propellant rocket motor possibilities for civilian exploitation as e.g. for the solution of steam gas for the steam turbines drive. These questions are in the time being very important mainly with respect to the so called clean energy sources.

One of several possibilities how to get such "clean energy system" source is the utilisation of convenient fuels and oxidisers combustion inside the gas generator combustion chamber, the majority of which are in gaseous state and designed at the base of liquid propellant rocket motor.

1. Introduction

Sophisticated military technique is a collection of principles which can be applied also in another the mainly civilian manner. The first possibility of such civilian application is the utilisation of liquid propellant rocket motor principle as it was in case of equipment for polyethylene production in the Chemical plant in Nováky, Slovakia in years 1976 – 1978 when the equipment was purchased from Hoechst Company (GFR). In the beginning it hasn't needed service properties (short generator service life regarding the mentioned). Therefore the plant managers were searching for an acceptable solution. The solution found in cooperation with the MA in Brno, department of rocket weapons when the carrying out of the task "*REACTOR*" reached the respective and convenient solution of generator service life [1].

Another possibility of civilian application was the solution of energy source especially in cases of stationary energy sources accidents, when supply of thermal energy endangers the population life conditions (as e.g. accident in the Electric Power Station Opatovice in late history). Energy source has to serve for required demands of thermal energy in all cases of stationary resources accident. The magnitude of spare should be chosen so that interruption of energy supply regarding the time would be minimum, but that there will be secured the maximum reliability. The higher will be the energy source, the higher will be the *investment, operational* and *working* costs. This in consequence will influence the price of thermal energy, (i.e. the built-up of spare stationary source having the power of about *40 MW* can be assumed the investment costs reaching the sum of about *70 millions* Czech crowns). On the contrary the smaller will be the energy source the investment, operational costs will be the lower. Therefore the energy source could be proposed for the power of about *5 MW*, which surely will influence the costs as well as the source dimensions (including its mass). This can contribute to more suitable conditions of its real utilisation and also to the creation of a needed source composed generally *n-units*. Moreover, such solution will also be more convenient for its mobile utilisation [2].

Nowadays, attention is being paid to energy sources throughout the world (e.g. German Federal Republic, Norway and some other states). The solution principle is very similar to the mentioned, one, i.e. the principle of gas generator working on the basis of rocket motor.

As it is clear from the above mentioned; the solution of these tasks, when there is applied the theory and design from the sphere of rocket propulsion, used on purely civilian needs seems to be very important.

2. Principle of liquid propellant rocket motor as a source of energy

The aim of this paper is to give some general hints with regard to the thermal energy source having the required power, minimum dimensions and minimum overall mass and which should be able to secure relatively low investment and operational costs. Presupposed thermal energy source could also serve as the *mobile* one during shutdown or accidents of stationary thermal energy sources.

Development of such energy source which can produce the steam gas mixture should operate on the principle of *liquid propellant rocket motor* – respectively *gaseous propellant*. Inside the gas generator combustion chamber there will be burnt *gaseous* or *liquid* fuel (e.g. carbon oxide, natural gas etc.).

The oxidizer could either be oxygen (O_2) or air (compressed). Generator system will be cooled by water; which also will be injected into the stream of combustion products inside the generator combustion chamber. Due to the water evaporation the combustion products stream will be cooled to the required value of temperature. The created steam gas mixture will be applied as the water steam produced by boilers, i.e.

it will be used for the heating of water inside the heat exchanger or in another technologic process. This presupposed equipment should be able to drop the build-up costs for stationary energy source.

In case of spare energy source it seems to be assumed that the fuel will be *natural gas* (i.e. the fuel based on hydrogen and oxygen eventually in liquefied state) and the oxidizer should be *gaseous oxygen* (O_{2g}) or compressed air.

Utilisation of compressed air as oxidizer regarding the time of spare energy source seems to be more convenient solution when compared with utilisation of gaseous oxygen. The presupposed equipment which will use air as "*O*" will probably produce the combustion products having relatively lower burning temperature, but, on the other hand, such solution would contribute to better cooling conditions of this system. The utilisation of compressed air in comparison with gaseous oxygen perhaps will lower the costs with respect to oxidiser production (when compared with O_2). Therefore such solution will be more economical one.

The solution principle of steam gas formation is schematically shown in Fig. 1 [2].

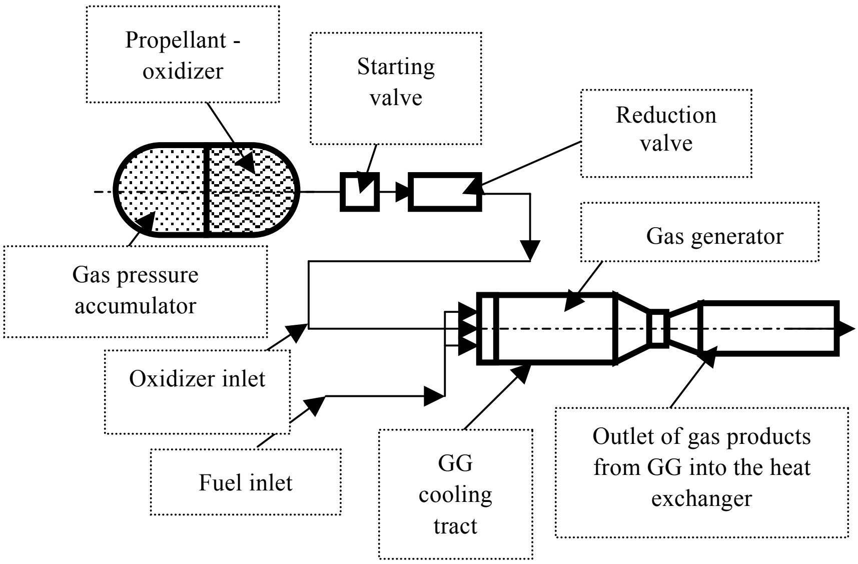

Fig. 1. Principle scheme of steam gas formation

***G**as **g**enerator – (GG)* convenient principle being formed by ***c**ombustion **c**hamber – (CC),* provided with so called *cooling tract* which serves for GG CC cooling. Into the GG CC will enter "F" and "O" components. There will be used so called *injection head* provided with the system of *injectors*. Components of chosen kind of *propellant* will be mixed and after mixing and ignition they will burn. In the course of used propellant will be released the heat the amount of which represents the energy which can be used in thermal energy source. Gas generator injection head should be arranged so that propellant components have to be uniformly distributed through the GG CC diameter, which could secure appropriate temperature distribution. Injectors of GG CC have to be solved so that the gases composition will approach to *stoichiometric mixing ratio*. Inlet of gaseous propellant into the GG CC should be controlled so that together with approximately constant value of mixing ratio (*ratio between mass flow rate of oxidizer and mass flow rate of fuel*) could be secured by convenient regulation system (evidently of electronic type).

The burning of used propellant take place at high temperatures (more *than 4000 K* in case of oxidizer e.g. gaseous O_2, in case of compressed air the burning temperature will be lower *than 4000 K*) and working pressure (e.g. *2 MPa*) will require the unusual construction of GG CC with *independent cooling tract*. Cooling agent (*coolant*) will be the water (*H_2O – in liquid state – gaseous components haven't cooling effects*). Big temperature gradients in GG CC will therefore require the application of the so called *outer cooling* and *inner cooling* combination. Principle scheme of GG for spare energy source is evident from Fig. 2 [3].

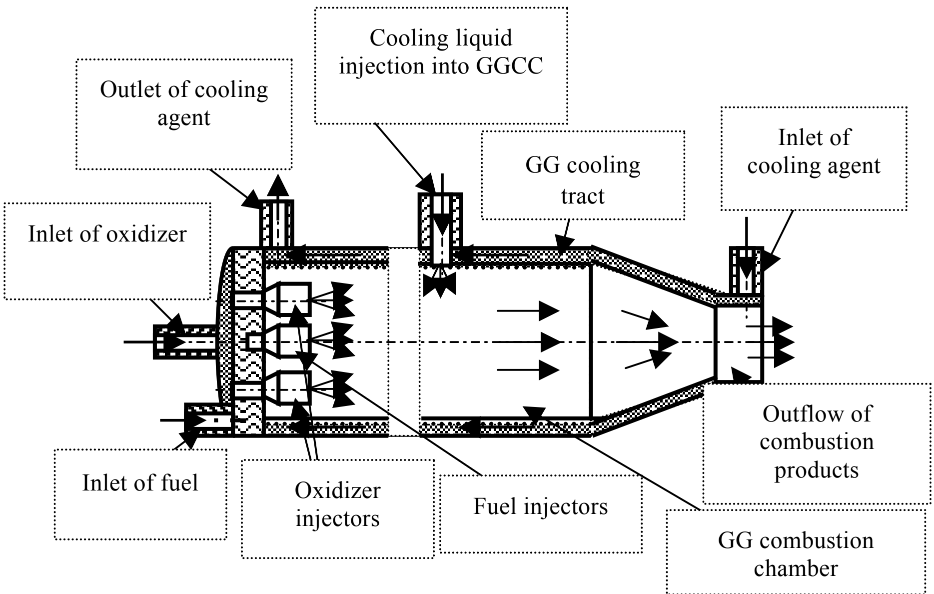

Fig. 2. Scheme of gas generator as energy source

Propellant combustion products in GG CC have high temperature when flowing out from GG CC. Cooling liquid (water) being used as coolant after passing through the cooling tract is as a rule injected backward to the GG CC (into the flow of combustion products). Water droplets due to the combustion products temperature quickly evaporate. This partially consumes heat energy and simultaneously it is cooled to the required temperature. The created steam gas contains even *(90 ÷ 95) % water steam*, and the remainder are *carbon oxides,* i.e. till *(10 ÷ 5) %*.

Steam gas can further be used in a similar manner as the steam produced in boilers, i.e. the water heating in *heat exchangers* or in the other technological equipment (e.g. in boilers).

Heat exchanger will use the produced steam gas which will be led through the piping system to the so called *partial cooler* where the final steam condensation will be finished. No condensed carbon oxides will be led into the ambient atmosphere (analogically as the air in standard steam condensers). Regarding the fact that condensation being led out from the heat exchanger will contain certain part of carbon oxide will be necessary to solve some questions related with the choice of appropriate construction materials of such equipment. Possible principle scheme is shown in Fig. 3.

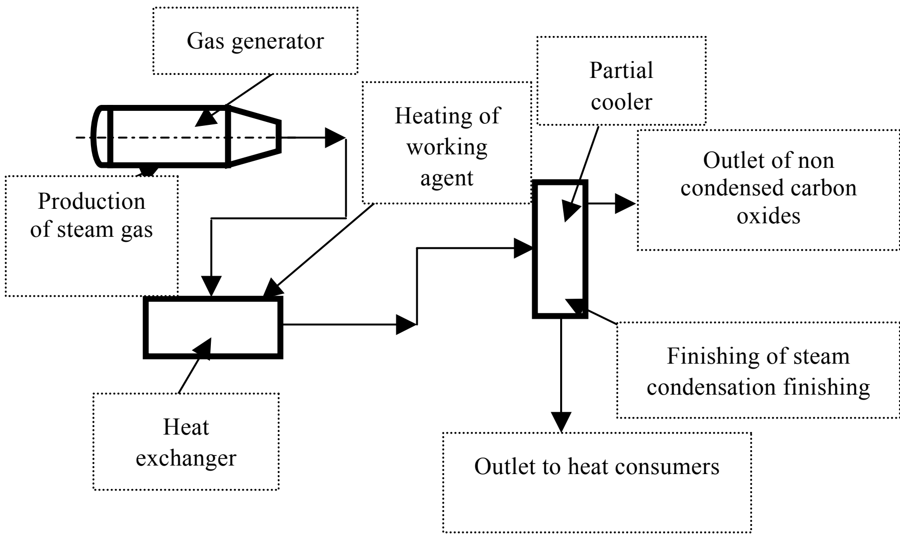

Fig. 3. Principle scheme of steam gas production

As mentioned above, inside the GG CC will be burnt gaseous propellant (rarely liquid propellant – carbon oxide) in conjunction with oxygen (in gaseous state) as oxidizer. Gas generator system will be cooled by the water, which will be injected into the stream of combustion products. Due to the water evaporation the combustion products stream will be cooled to the required temperature. Produced steam gas mixture will be used in boilers, i.e. will be used for the water heating in the heat exchanger or suitable technological equipment. Small dimensions of such system allow its displacement on appropriate transport means. Presupposed facilities allow the decrease of costs needed for the constructing of stationary spare energy source.

The mixture of vapours and gases will contain approximately *90%* of water steam; the remainder will be carbon oxide (C_2O_4). Steam gas mixture will be used similarly to the steam going out from steam turbines, i.e. for water heating inside the heat exchanger. The system described in case of steam gas mixture has to be completed by the complementary task, i.e. the task related with outlet of carbon oxide from the equipment presupposed (into the ambient atmosphere or to exploit it in another way).

Regarding the above mentioned facts there are possible different ways of this task solution. One of these possibilities is the purchase of technology from existing producers. Another possibility is the beginning of domestic development.

In case of some parts of energy source purchase, e.g. gas generator and its accessories the price, according to available information is about *2,5 mil USD* (i.e. in converted into the Czech crowns it is about *70 mil. CZK*). Technology purchase abroad hasn't always been economical acquisition. Upgrading these resources for domestic development would be apparently more convenient, regarding the fact that in the Czech Republic there exist the knowledge and in the future this could contribute to the possible commercial utilisation.

The University of Defence in Brno has clever employees able to solve the tasks related to the convenient gas generator for clean energy sources, eventually to realize spare energy source in practice.

Project of heat energy source is therefore the solution which conveniently applies the liquid propellant rocket motor principle for the design of *gas generator* of steam gas when using carbon oxide fuel and compressed air as oxidiser. Gas generator of steam gas mixture be completed by effective regulation system could replace stationary heat energy sources. The presupposed solution is able to reduce the equipment dimensions as well as its overall mass and therefore can be also of the *mobile* type, which in case of accident allows quick relocation to the place of its utilisation. With respect to used kind of fuel and oxidiser the equipment is practically *ecologically clean* and will not have non required effects on human environment. The investment and operational low costs of the presupposed mentioned equipment with respective output, are acceptable for its real use and its further commercial use.

Gas generator (GG) secures stoichiometric burning with minimum gas emissions as e.g. *CO, NO* etc. High pressure gas being the result contains steam and CO_2. Steam being obtained is the result of effective direct burning of propellant in contrast to conventional technologies (i.e. boilers).

Moreover, multiple cooling stages (containing controlled water injection together with cooling tracts) secure stoichiometric presupposition in order to reach the needed steam temperature before input into the high pressure turbine (see Fig. 4) [4].

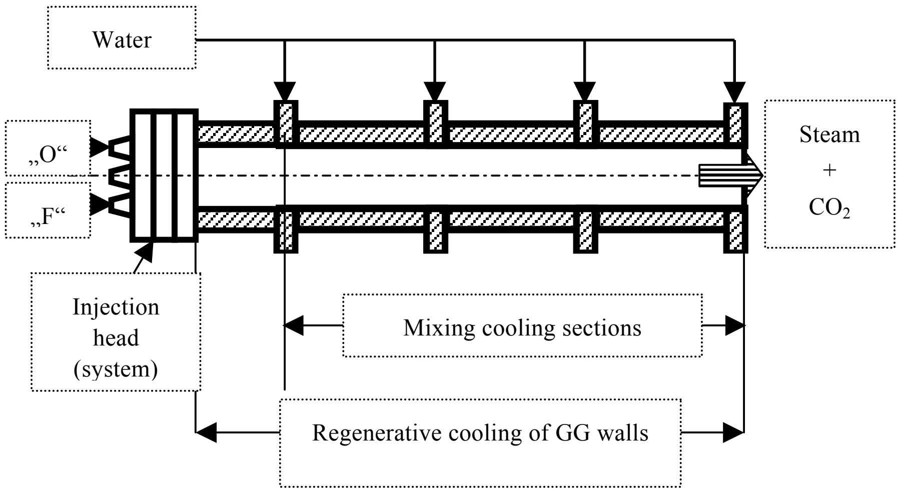

Fig. 4. Gas generator scheme

Gas generator having suitable mixing of fuel and oxidizer and circulating water as coolant is able to provide the steam having required temperature and pressure, i.e. magnitudes needed for the turbine function. Therefore it is necessary to have at one's disposal the turbine parameters determining the efficiency of working cycle.

Gaseous and thermodynamic effect of CO_2 on the steam propulsion is a minimum one. The main presupposition when neglecting the work during passage through individual turbine stages is securing of the fact that condensation (usually leads to the formation of slight carbon and corrosive acids) is the side effect in case of low pressure turbines in connection with the cooler.

Utilisation of such propulsion gas is as a rule proven practice of geothermal steam turbines.

The equipment for generation of working substance is partly compact; partly it doesn't contain any movable parts. Complexity together with technological solution is primarily associated with the injection head of the gas generator, which secures homogeneous mixing, control of the flame front (preclusive of local hot places) and the total heat control secures the GG production with conventional construction materials together with the water as cooling agent.

3. Conclusion

In conclusion, regarding all above mentioned it is possible to claim the following. The use of the liquid propellant rocket motor principle seems to be a proper contribution which can be utilised in clean energy systems, i.e. systems being regardful of living environment in contrast to thermal electric power stations combusting different kinds of solid fuels.

Clean energetic systems are in contemporary conditions the systems, which are in the centre of attention. Regarding till now published cases or solutions as e.g. in [4], it is evident systems being assumed in energetic frameworks are also based on LPRM principle (never mind that they are used in the majority gaseous components). They cooling systems mostly use as the coolant the water and all the cooling system is as a rule of the *regenerative* type. That is why there serious attention has to be paid the mainly to acceptable steam temperature used a source of high pressure turbines drive.

It is only necessary to add that the solution of effective cooling system of gas generator can start after the GG real proposal (design – i.e. regarding its real geometric dimensions).

The presented findings in this paper can be considered as a piece of information. Theoretical and experimental solution of gas generator (with its equipment) is in the Czech Republic conditions possible and real.

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