ENVIRONMENTALLY FRIENDLY FUEL SYSTEM FOR LIQUEFIED GAS CARRIER PROPELLED WITH 45 MW MAIN PROPULSION PLANT

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Abstract

This paper describes the problem of improvement in environment protection by application "e nvironment friendly" fuel natural gas for ship propulsion. In the paper the most suitable type of ship main propulsion system using natural gas was take into consideration. Propulsion using low speed diesel engine, medium speed diesel engine, steam turbine and c ombined systems were taken into consi deration. As a result of analysis it was affirmed that COGE S (Combined Gas Turbine and Steam Turbine Integrated Electric Drive System) is the most suitable pr opulsion plant to be fed with natural gas in contrary to ship diesel engines w hich adaptation to nat ural gas use still is in initial condition. COGES type propulsi on plant consists in t hermodynamic join of gas turbines and steam turbi nes. All turbines drive generators of main ship power station supplying simultaneously electric power to ship main propulsion electric motors and to ship electric network as well. It is suggested to use natural gas as fuel for gas turbines. Steam turbines are driven by steam produced in boilers warmed by gas turbines exhaust gases. This way a high efficiency of ship propulsion is obtained. The simplest source of na tural gas is cargo carried by LNG (Liquefied Natural Gas) carriers. The preliminary project of such a carrier fuel system is presented in the pape r. In addition conditions of application, advantages and disadvantages of natural gas fuel system are discussed.

***Keywords**: natural gas ship propulsion, COGES propulsion system*

1. Introduction

The paper is the contribution of Marine Propulsion Plants Department of Gdynia Maritime University in discussion concerning application of environment friendly propulsion of seagoing ships. According to authors opinion the reduction of environment harmful substances from ship main propulsion exhaust gases is possible by change of fuel used from heavy oil to natural gas. Actually, liquefied natural gas carries (LNG carriers) can be relatively easy propelled by natural gas as the natural gas is cargo of such ships. The liquefied gas is transported under atmospheric pressure in temperature –163ºC. During the shipment despite high class of cargo tanks insulation a heat penetration into tanks takes place so the liquefied cargo vaporises. Vaporisation is about 0.15% of cargo daily. Having in view protection against cargo losses the vaporised gas should be again liquefied and stored in cargo tanks. The evaporated cargo can be also used for ship propulsion. However at present time the natural gas is not widely used in this purpose. Mainly it is the result of technical problems in adaptation of marine diesel engines for natural gas use. Presently, only the numbers of LNG carriers propelled by steam turbines are equipped with gas fired main boilers. Application of COGES type propulsion plant with gas turbines supplied with natural gas as fuel is justified due to high energetic efficiency, smaller dimensions and environment protection. Gas turbines burning natural gas are widely used in onshore power stations and thermal-electric power stations.

Proposal of gas turbines in COGES propulsion system supplied with natural gas on liquefied gas carrier is presented in the paper. There is also short description of COGES propulsion system and analysis of use the carried by LNG carrier natural gas as fuel for such a ship propulsion. The next proposal of fuel system for 45 MW ship propulsion plant, which can be applied on new generation LNG carrier with carrying capacity 300000 m^3 of liquefied natural gas, is given.

2. COGES type marine propulsion plant

Possibilities of propulsion of LNG carriers by gas turbines thermodymically joined with steam turbines in Combined Gas Turbine and Steam Turbine Integrated Electric Drive System (COGES) were presented by researches of Marine Propulsion Plants Department of Gdynia Maritime University on KONES 2007, 2008 and 2009 conferences. COGES propulsion system is characterised by high efficiency, turbines are relatively simple constructions easy in operation and maintenance and the use of natural gas minimises emission of environment harmful components of exhaust gases.

Configuration of COGES propulsion system is shown in Fig. 1. Gas turbines drive alternators 4. Exhaust gases from gas turbines heat steam boilers 3. The steam produced in boilers drives turbine 2 of steam turbo-alternator and is used for ship heating purposes. The system incorporating exhaust gas heated recovery boilers and steam turbo-alternator considerably increases energetic efficiency of propulsion, which is competitive to other types of ship propulsion systems [5]. Gas turbo-alternators and steam turbo-alternator create central onboard power station supplying ship main propulsion thrusters 7 and via transformers the ship electric network as well. For main propulsion modern azipod thrusters (Fig. 2) can be used. Azipods have electric motors inside pods horizontally rotational under ship stern. Actually the power of one azipod achieves 20 MW. Azipods are simultaneously very effective steering gears. There are no separate auxiliary electric generating sets in the ship engine room. The electric power is produced by central onboard power station with higher efficiency than in traditional propulsion with separate generating sets.

In COGES propulsion system, which fuel system is described in the paper the suggested power distribution between gas turbines and steam turbine is 75/25 %. Thus the power of gas turbine alternators is 2^x17180 kW and steam turbine alternator is 1^x10640 kW. Total power of onboard power station is 45000 kW. The effective efficiency of the system is 53.7 % [8]. The following machines are proposed in described propulsion system: two gas turbines Siemens SGT-500, one steam turbine Siemens SST-150 (Fig. 3), two exhaust gas heated recovery steam boilers Aalborg MISSION^{TM} WHR-GT (p=4MPa, D=50000kg/h) and auxiliary gas fired steam boiler Aalborg MISSION^{TM} D (p=4MPa, D=65000kg/h) (Fig. 4).

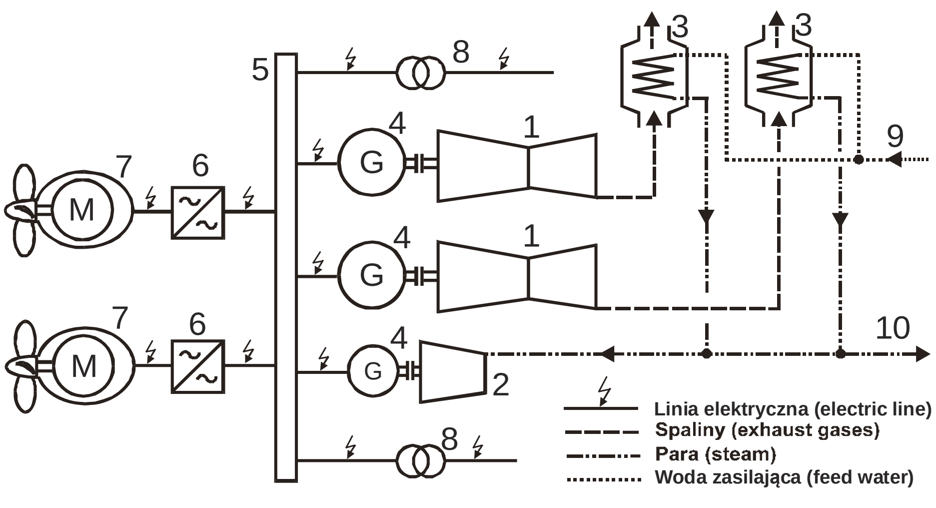

Fig. 1. COGES type propulsion plant 1 - gas turbine, 2 - steam turbine, 3 - exhaust gas heated recovery boiler, 4 - generator, 5 - main switchboard, 6 - frequency converter, 7 - azipod thruster, 8 - transformer, 9 - feed water inlet, 10 - heating steam outlet

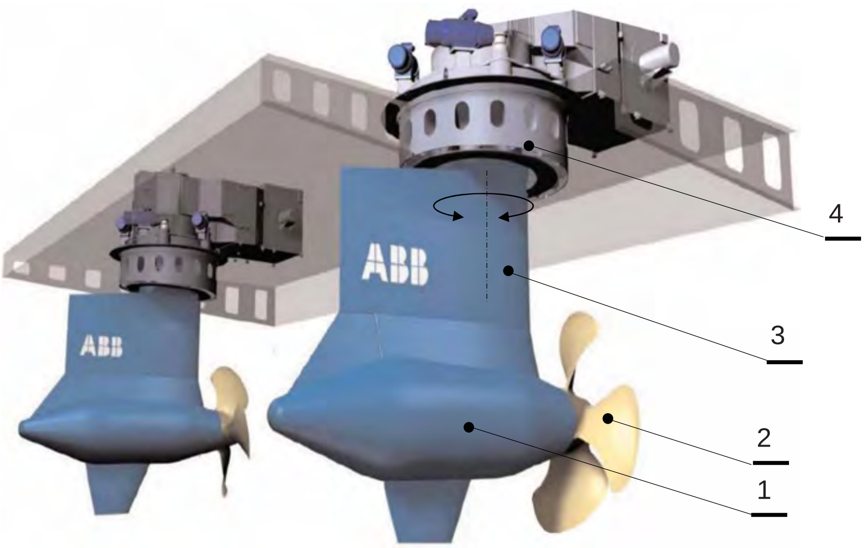

Fig. 2. Azipod thrusters ABB 1 - pod, 2 - propeller, 3 - azipod rudder fin, 4 - azipod slewing gear

a) b)

Fig. 3. a) Gas turbine Siemens type SGT-500, b) Steam turbine Siemens type SST-150

a) b)

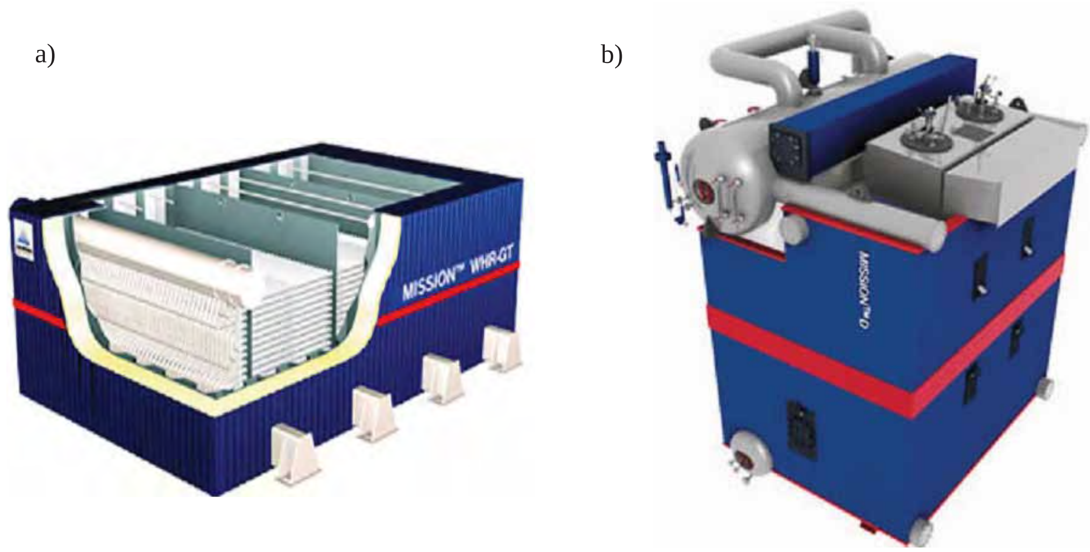

Fig. 4. a) Exhaust gas heat recovery boiler Aalborg MISSION^{TM} WHR-GT, b) Gas fires auxiliary steam boiler Aalborg MISSION^{TM} D

Nowadays marine COGES type propulsion systems are used on passenger cruises where gas turbines are supplied with marine diesel oil. The proposal of natural gas fed gas turbines is described in point 3.

3. Natural gas fuel system for COGES marine propulsion

The scheme of gas fuel system for LNG carrier propelled by COGES type propulsion is shown in Fig. 4. The liquefied gas cargo is carried in cargo tanks 1 under atmospheric pressure in temperature –163ºC. Gas vapours are drawn from cargo tanks by low pressure compressors 4 (piston compressors Cryostar CM 400/55, discharge pressure about 0.2 MPa, gas discharge temperature about – 111.5ºC, capacity 39.6 m^3/h) and pressed to heaters 5 where temperature increases to about 30ºC. Low pressure gas can be used in auxiliary steam boiler 9. Regarding pressure in gas turbines combustion chambers to supply gas turbines the gas should be compressed to about 2.5 MPa in high pressure compressors 6 (piston compressors Reavell 5405, discharge pressure about 2.5 MPa, suction temperature about -10°C, discharge temperature about ok. 30°C, capacity 12 m^3/h). The amount of evaporated gas cargo depends on environment temperature.

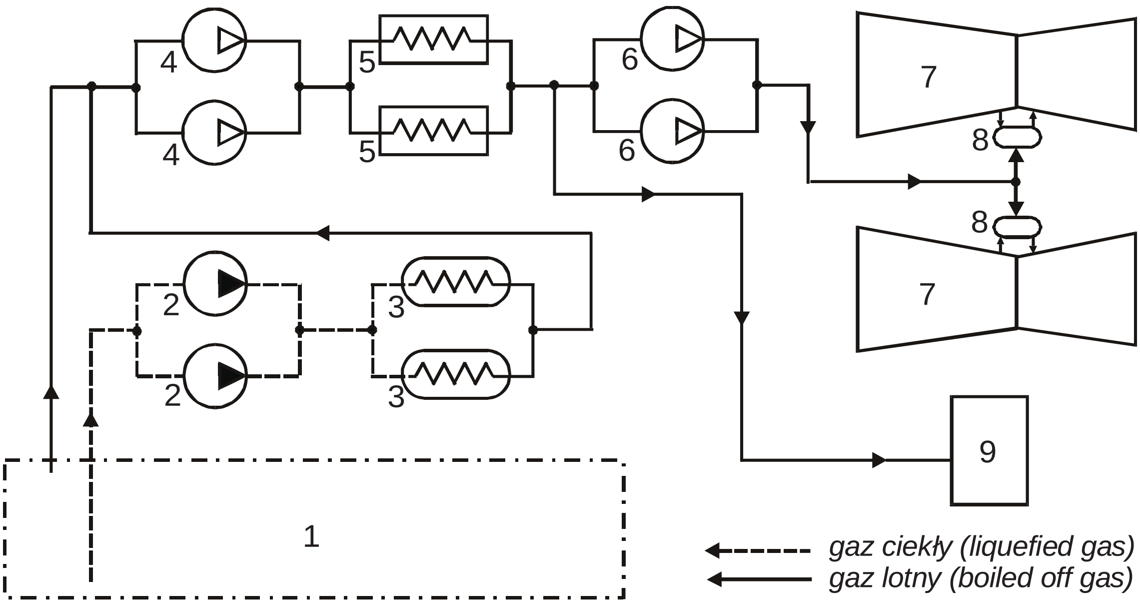

Fig. 4. Gas turbines fuel system on liquefied natural gas carrier 1 - LNG cargo tanks; 2 - liquefied gas pump; 3 - liquefied gas vaporiser; 4 - low pressure compressor; 5 - heater; 6 - high pressure compressor; 7 - gas turbine; 8 - gas turbine combustion chamber; 9 - gas fired auxiliary steam boiler

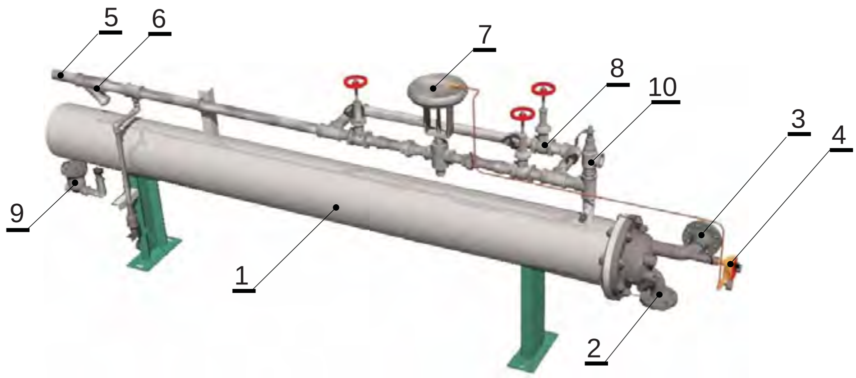

Fig. 5. Liquefied gas vaporiser 1 - casing; 2 - liquefied gas inlet; 3 - liquefied gas outlet; 4 - gas temperature sensor; 5 - heating steam inlet; 6 - filter; 7 - heating steam inlet controller; 8 - heating steam inlet manual control valve; 9 - heating medium outlet with steam trap; 10 - safety valve

In case to low amount of evaporated cargo the system can be supplied with liquefied gas by means of pumps 2 and vaporisers 3. Each modern LNG carrier is equipped with gas reliquefaction system. Machines and equipment of reliquefaction system and cargo system can be used to supply gas turbines with gas as a fuel. Thus the gas fuel system does not need additional machines and equipment. Only additional piping connections with ship engine room are needed.

According to [8] the daily consumption of LNG fuel by described main COGES propulsion runs with full power (45 MW) is 287.4 m^3 (139.4 tons). The daily evaporation of gas cargo is about 0.15%. As the capacity of LNG carrier is 300000 m^3 the daily evaporation achieves 450 m^3, which fully covers main propulsion demand. The remaining evaporated gas should be reliquefied and returned to cargo tanks. During ballast voyage when the small amount of gas cargo remains on board it is necessary to use in fuel supply system liquefied gas pumps 2 (Ebara 2EC – 092, capacity 50 m^3/h, suction temperature –163°C, electric motor power 18 kW). Pumps transfer the gas liquid to vaporisers 3 (Fig. 5) and next it is drawn by low pressure compressors.

4. Conclusions

Application of gas fuel system to supply gas turbines used in COGES type propulsion on LNG carrier is a result of following premises:

- determination to improve environment protection in sea transport by use natural gas considered “ecological fuel”,
- decision to build the ship propelled by COGES system due to its unquestionable advantages; besides advantages mentioned in point 2 it can be expressed that COGES propulsion engine room is 30% less in space than in case of traditional low speed diesel engine propulsion; it makes possible to enlarge ship cargo space (it is shown in Fig. 6),
- easy application of natural gas as a fuel on LNG carrier due to possibility of gas reliquefaction system use.

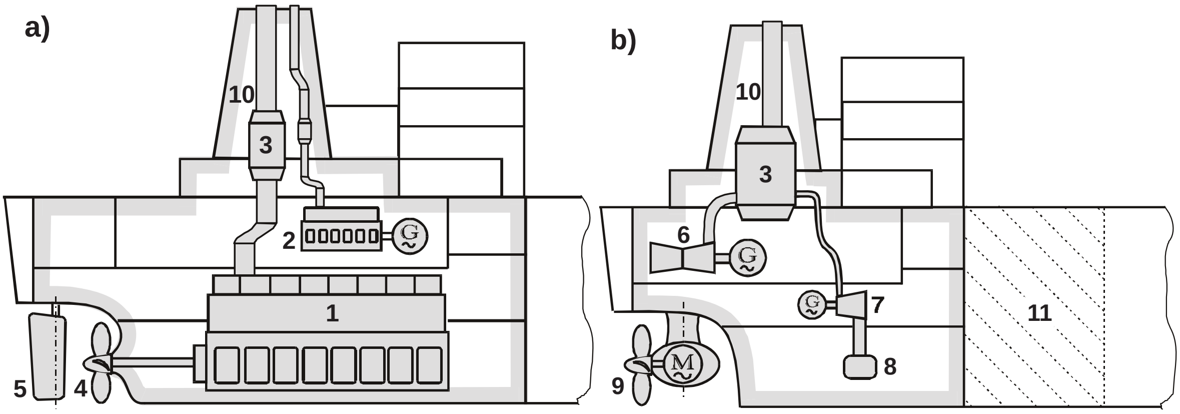

Fig. 6. Comparison of machinery space of LNG carrier propelled by low speed diesel engine (a) and COGES system (b) 1 - low speed diesel engine; 2 - diesel generator unit; 3 - heat recovery steam boiler; 4 - propeller; 5 - rudder; 6 - gas turbine generator unit; 7 - steam turbine generator unit; 8 - condenser; 9 - azipod thruster; 10 - exhaust gases outlet; 11 - additional cargo space

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