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REMARKS ON UTILIZATION OF MARINE TRENT 30 GAS TURBINE AS PRIME MOVER ON VESSELS

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Abstract

Utilization of gas turbines on vessels is a reality. It was presented the examples of utilization on ships of United States Navy and the Rolls-Royce suggestion for sharing on merchant shipping. It was mentioned the advantages of gas turbine MT30 with nominal power 36 MW or 40 MW prepared for marine utilization. It was stated the characteristics of specific fuel consumption, the shaft power rating, the MT30 operating envelope with propeller characteristics as a power receiver. It was given propositions of vessel types for MT30 utilization. It was discussed the remarks on maintenance requirements and needed systems for upkeep the turbine in good technical state for the possibility of full nominal power independent on ambient temperature. It was discussed the requirements of emissions from exhaust gasses to the atmosphere in comparison gas turbines to diesel engines as a one of important problems for utilization engines as prime movers on vessels in merchant shipping. In the end, some final remarks with Rolls-Royce statements are presented.

Keywords: *marine prime mover, gas turbine, propulsion, gas-electric plant, gas turbine utilization*

1. Introduction

The Rolls-Royce gas turbine of MT30 is a marine version for utilization as a prime mover in mechanical and electrical arrangements. It was utilized in the American States Navy (USN) (Fig. 1, 2). The American States Navy is the biggest consumer of MT30 and RR4500 principally in Integrated Full Electric Propulsion (IFEP) [2]. At present, the Rolls-Royce tries to expand the engine utilization on vessels of merchant shipping. The most limitation of MT30 is its power 36 or 40 MW. The proposition may concern rather big or very speedy vessels. The Rolls-Royce has prepared other gas turbines for marine utilization like RR4500 at 3.9-4.3 MW, Allison 501 at 5.5 MW, MT5 at 5.7 MW, Marine Spey at 18 MW, RB21 at 25 MW and MT50 at 50 MW. The basic problem of gas turbines there is no types of series. Having on-board different types of gas turbines we have a big problem with needed (requirements of classification society) spare parts for them.

The next one is increased specific fuel consumption (in comparison to diesel engines) and increased fuel costs.

2. The advantages of MT30

The adaptation of MT 30 for marine application allows to reach the flat characteristics of power independent from ambient temperature from –40ºC up to 37.8ºC (100ºF) [1]. MT30 gas turbine is capable of:

– providing stable, continuous operation at any power between the maximum and minimum (about 0.7 MW),

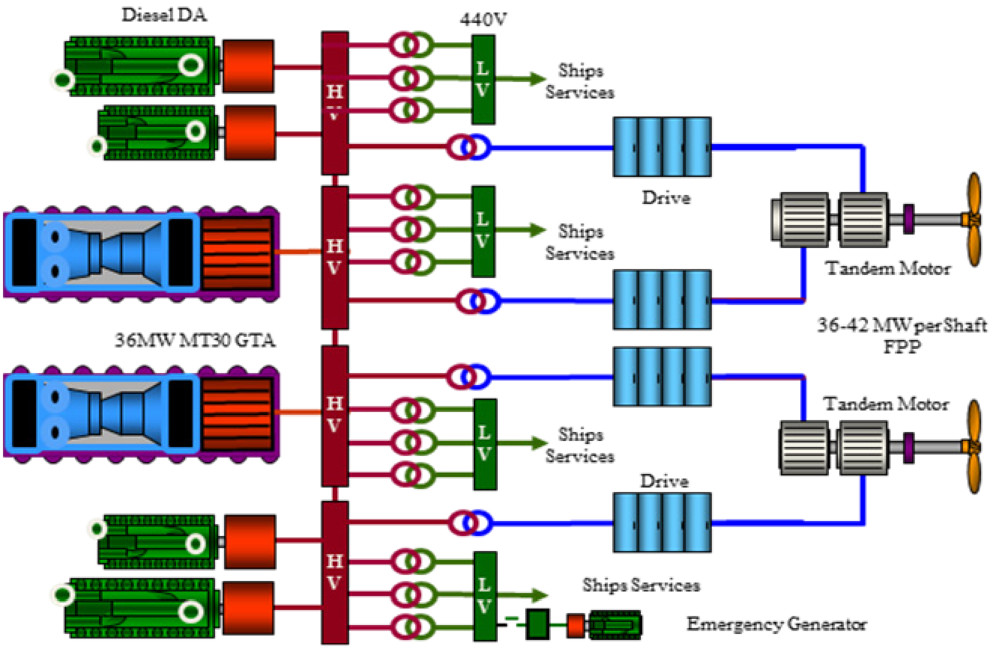

Fig. 1. Propulsion system on air craft carrier (Royal Navy QE class) with two gas turbines MT30 and four diesel engines (CODAG system) [2]

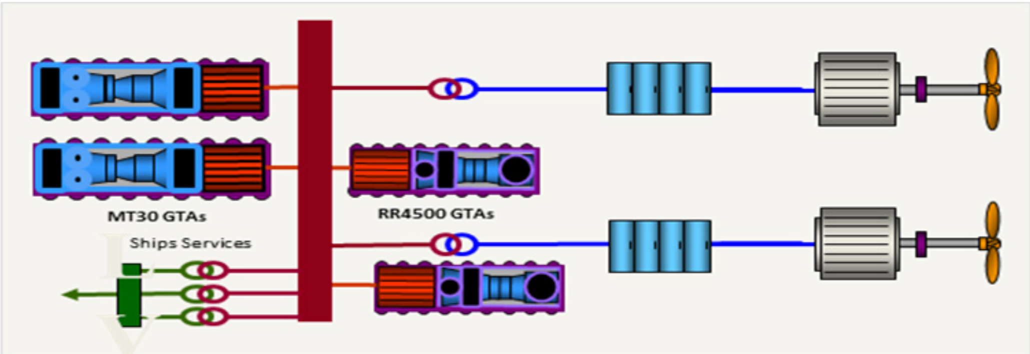

Fig. 2. Propulsion system on USN DDG1000 with two gas turbines MT30 and two RR4500 [2]

- the power turbine inertia is 170 kg·m^2, the propulsion system shaft shall be greater than 550 kg·m^2 (to prevent the engine shutting down in the event of a full load shed – propeller out of the water),
- very short indicative time to achieve defined power from idle condition: to reach output power of 4 MW the taken time is 12 s and next about 1 MW/s to nominal power 36 MW in time of 38 s from idling,
- the MT30 has no requirement for special cool-down procedures or restrictions on restart following normal shutdown. It is very important for vessel propulsion system in the event of requirement of an immediate restart,
- the overall heat rejection is 38 kW with machinery space temperature of 35ºC, it needs the air mass flow of 15 kg/s at inlet temperature of 15ºC,
- the power to mass ratio (for the MT30 package without gearbox) is about 1.1-1.25 kW/kg,
- the specific fuel consumption (SFC) is at nominal power 0.216 kg/kWh, it means that the thermal efficiency of MT30 is about 39.0% (see Tab. 1),
- the start cycle is designed to accelerate the engine from initial rotation to idle in less than 90 s (typically less than 80 s) (Fig. 3) but in normal situation during Auto Start the engine is held at idle for 5 minutes before the throttle is available (warming after start),
- the specific work is 333.3 kJ/kg (power to air mass flow ratio) [1].

Tab. 1. Specific fuel consumption variation with shaft power of MT30 at ambient temperature 15°C [1]

Power [MW]	Power turbine speed [rpm]	SFC [kg/kWh]	Inlet flow [kg/s]	Exhaust flow [kg/s]	Exhaust gas temperature [K]
40	3418	0.216	120	122	759
36	3300	0.220	115	117	742
32	3173	0.225	110	112	728
28	3035	0.231	105	106	711
24	2883	0.240	99	100	695
20	2713	0.251	93	94	679
16	2518	0.266	85	86	661
12	2288	0.290	77	78	641
8	1999	0.345	70	70	619
4	1586	0.473	57	57	593
Idle 0.7	920	1.089	33	33	560

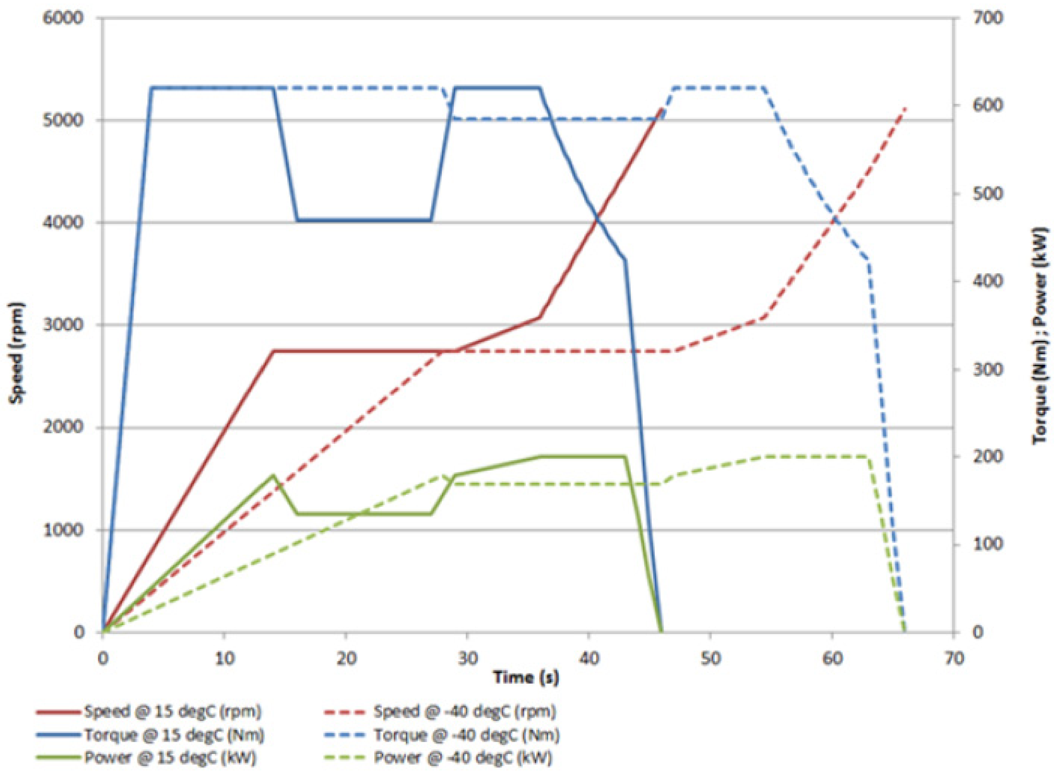

Fig. 3. MT30 shaft power rating at 15°C (continuous line) and –40°C (discontinuous line) of ambient temperature [1]

The Rolls-Royce for gas turbine MT30 has certificates from classification societies (from ABS, DNV-GL, Lloyd Register, RINA) confirming possibility for utilization as main engine on vessels and the type approval for nominal power of 36 and 40 MW.

3. MT30 operating envelope area

In mechanical propulsion system, the gas turbine drives the propeller through the reduction gearbox. Propeller is a specific power receiver. The constant pitch propeller (CPP) characteristics are given by the equation:

$$P = k \times n^x, \quad (1)$$

where:
P – required power [kW],
k – coefficient [according to other units],
n – rotational speed (turbine shaft or propeller shaft) [rpm],
x – exponent [–], the value depends on hull shape, vessel speed and type of displacement flotation, for preliminary analysis $x = 3$.

The most light conditions when the vessel resistance is the smallest and the most hard conditions when the vessel resistance is the greatest (red lines in the Fig. 4) create the area of change of propeller characteristics (green area with letter "a" – operational area of GT work) [4].

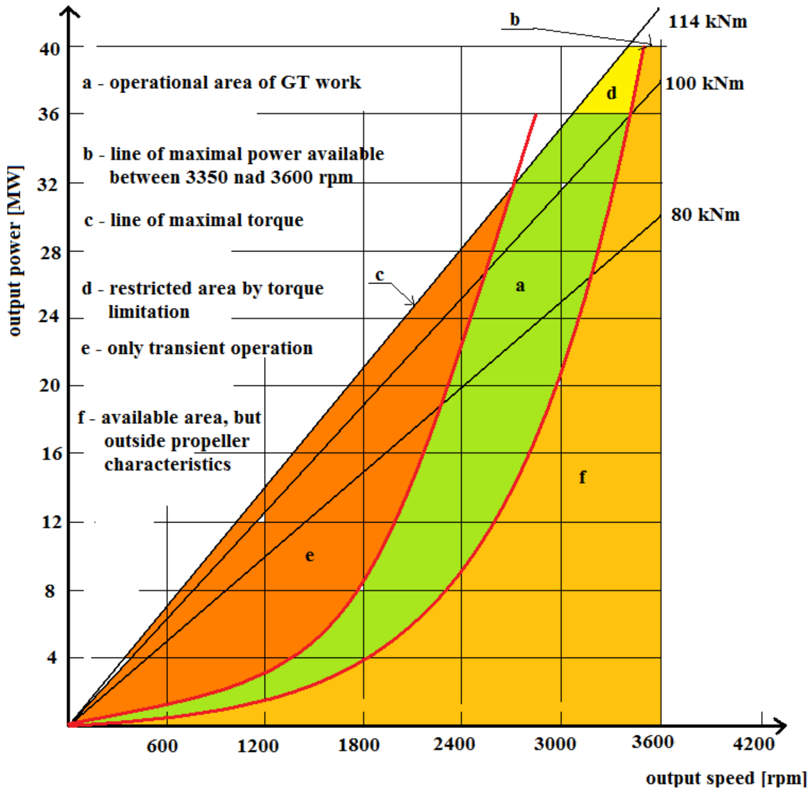

Fig. 4. MT30 operating envelope (area of MT30 work) [on base of 1]

The area "f" is available for GT work but is outside of propeller characteristics. The area "e" is limited only for transient operation. Maximal power of MT30 is available only between 3350 and 3600 rpm (additional area "d"). For the heaviest conditions at 2750 rpm it is available 32 MW of power because in that point it is reached the maximal torque (114 kNm). In reality the available characteristics starts from 920 rpm (idle) and minimum of 0.7 MW of power. Below the idle speed, the turbine works unstable. For propulsion purposes, the MT30 operating envelope area is good situated with the change of propeller characteristics (area "a"). It is important the gas turbine ought to work over 50% of load. There are no limits up to 32 MW, over that level the maximal torque is a limitation. At 50% of load, the specific fuel consumption is increased about 14% in comparison to 100%. It is an acceptable level.

4. Vessel types for utilization of MT30

Due to the nominal power of MT30 on level 36-40 MW the possibility of utilization as propulsion on vessels is limited especially in mechanical arrangement. The main engine on vessels ought to work on 50-90% of nominal load. It guaranteed low specific fuel consumption (high efficiency), not overloading, limited deposit forming (unburnt particles of fuel) etc.

It may be taken into consideration following types and size of vessels:

- LNG gas tanker of 180-220 thou. m^3 of cargo containment, as fuel may be used the gas from cargo tanks (boil-off gas),
- very large crude carrier (VLCC) of 180-300 thou. m^3 of cargo containment if the needed vessel speed is about 14-16 knots,
- big cruise liner, for the biggest one or speedy it may be used two MT30, especially in gas-electric (G-E) systems with possibility of COGES system (gas and steam system),
- container vessel in size of about 8 thou. TEU,
- very fast mono-hull vessel or speedy catamaran.

The presented list is not long. The barriers are the increased fuel costs, limited (so restricted) time of work gas turbines on vessels (small experience) and requirements for machinery crew (engineers with diplomas on turbine vessels).

5. Maintenance of gas turbine – compressor wash system

The maintenance of MT30 requires less than 90 minutes per week [2]. There is no “level 3” and “level 4” maintenance – it means no disassembly or lengthy internal maintenance on board so support lean operating (less members of crew). MT30 features modular design (important it is not a split case). The overhaul of gas turbine is more simple than diesel engine.

The hot turbine casings need cooling. It was done by water mist but to ensure that the casings are not damaged as a result of high quench rate, water mist droplet size must be controlled. The maximum flow is 25 dm^3/minute [1].

When the ambient temperature is low and a risk of icing is possible or due to high air humidity, the air bleed from third stage high-pressure (HP) compressor is available. The maximum bleed demand should not exceed 4 kg/s [1].

A periodic cleaning of internal components of gas turbine is a necessary. To reach high efficiency and full power of gas turbine it is needed to work with high internal efficiency of compressors and turbines.

For removal of salt deposits (marine application) a wash cycle using warm (60ºC), good quality potable water is recommended [1]. There is an integral tank heater in the MT30 package. In case of contamination with dirt or oily deposits, the Rolls-Royce (RR) proposed an approved aqueous wash fluid (CSS260). To minimize maintenance burden the frequency of required washing can be used an RR optimization. The washing system works at 60 bar of pressure, maximal flow 42 dm^3/minute, the volume water required is about 120-160 dm^3.

6. Emissions from gas turbines

Gas turbines are known from low emissions. The most often ways of decreasing emissions: nitrogen oxides, carbon oxide and particulate matters lead to increasing the fuel consumption and decreasing the efficiency. In 2004 [3] the MT30 has the specific fuel consumption (SFC) 0.201 kg/kWh (on gas as fuel) and 42% of efficiency. In 2016 [1] for the same turbine the SFC is 0.216 kg/kWh and 39% of efficiency. It means worsening (not improving!) mentioned parameters about 7.5%. It means respectively the 7.5% increase of carbon dioxide emission per specific energy. Typical exhaust gas composition from diesel engines and gas turbines (in the end of XX century) was presented in the Tab. 2. An example of nitrogen oxides emission is presented in the Fig. 5. For the present emissions from engines are lower (better) omitting the dioxide carbon emission (is bigger). Especially the nitrogen oxides emission was decreased to about 2 ppm for gas turbines of course. For diesel engines due to annex VI (MARPOL Convention) from the year 2016 for all new built engines the tier 2 level ought to be fulfilled (below the 13.4 down to 9.8 g NO_X/kWh) – recalculating about 1800-2500 ppm and on the Environmental Control Areas (ECAs) the tier 3 level (below 3.4 down to 2 g NO_X/kWh) – recalculating about 370-630 ppm.

Tab. 2. Typical exhaust gas composition from diesel engines and gas turbines (in the end of XX century)

	Diesel engine	Gas turbine
Nitrogen (N_2)	75-76%	66-72%
Oxygen (O_2)	13-14%	12-18%
Carbon Dioxide (CO_2)	4.6-5.6%	1-5%
Steam (H_2O)	5.3-5.4%	1-5%
Nitrogen Oxides	110-1500 ppm	20-220 ppm
Carbon Oxide	60-200 ppm	5-150 ppm
Particulate Matters	150-180 ppm	5-40 ppm

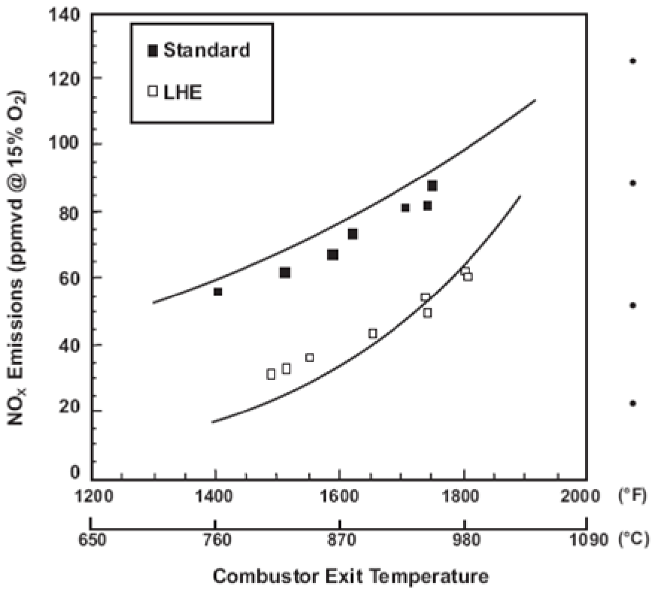

Fig. 5. Data from field-test for simple cycle gas turbine MS5002 (from 1997)

The NOx emission depends mainly on the maximum temperature in the thermodynamic cycle. For gas turbines, it is the combustor exit temperature. If the load (the torque) is lower, the emission is quickly decreasing. The different situation is when looking for the carbon oxide emission (Fig. 6). At partially load (especially below 50% of nominal) the CO emission is rapidly increased.

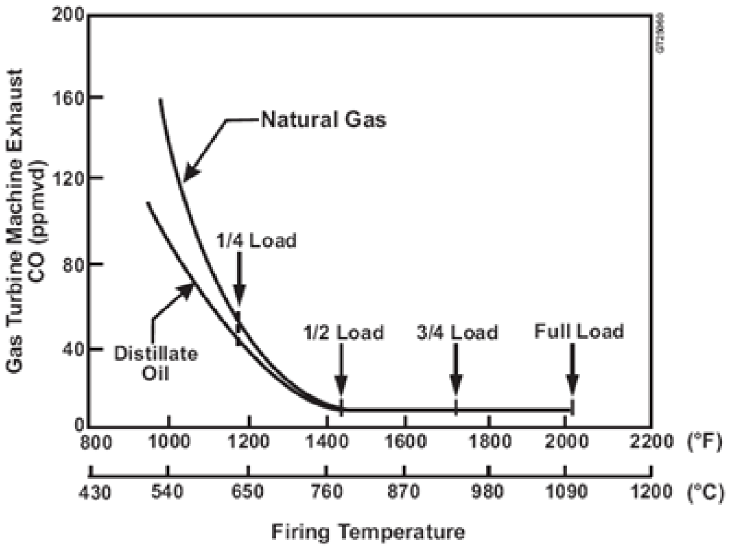

Fig. 6. CO emissions for gas turbine MS7001EA (from 1997)

7. Final remarks

The utilization of gas turbines as prime movers on vessels is a reality. The Rolls-Royce MT30 is the next one especially to many advantages:
- a modular engine increases engine availability,
- decreased time for maintenance (module replacement and repair),
- lower overall maintenance costs,
- ease of transport and storage (especially for engine of 40 MW of power),
- reduced spare engine holdings,
- engine issue may be rectified in module swap out rather than requiring a new engine [1].

The environmental low emissions requirements turn to the interest of gas turbines. On special areas (ECAs) it is a proposition necessary to consider especially for the biggest vessels like cruise liners which are sailing to Alaska or Antarctica waters. In many popular ports for cruise liners, ro-ro-es, ferries etc. are or should be quickly prepared additional requirements for restricted emissions to the atmosphere from vessel engines.

References

[1] Edge, W., *36 MW MT30 Mechanical Drive Package – Technical Description*, Rolls-Royce, March 2016,.
[2] *The Rolls-Royce MT30 Marine Gas Turbine*, presentation, 2016.
[3] *The Rolls-Royce Marine,* presentation, 2004.
[4] Cwilewicz, R., *Okrętowe turbiny gazowe,* Fundacja Rozwoju Akademii Morskiej w Gdyni, Gdynia 2004.