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ASPECTS OF COMBUSTION AND COOLING PRINCIPLES IN MARINE GAS TURBINES

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Marine gas turbine propulsion engine is derived from the turbo-shaft aero engine which has achieved many millions of flying hours in commercial aircraft. A typical application of the gas turbine is as the cruising engine in COGOG propulsion machinery. The combustion casing is a cylindrical housing that encloses a group of flame tubes, positioned in the annulus formed between the casing and an integral heat shield assembly. The air intake combustion chamber is used for the burning and cooling process. Cooling air is required to insulate components against heat radiation to prevent leakage of hot gases from the gas stream and to dissipate heat from the turbine assemblies.

Keywords: combustion chamber, gas turbine, airflow

АНАЛИЗ ПРИНЦИПОВ СГОРАНИЯ И ОХЛАЖДЕНИЯ В МОРСКИХ ГАЗОВЫХ ТУРБИНАХ

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Морской газотурбинный силовой двигатель является производным от турбинного авиационного двигателя, налет которого на коммерческих самолетах составляет многие миллионы часов. Типичное применение газовой турбины - маршевый двигатель в двигательной установке COGOG. Кожух сгорания представляет собой цилиндрический корпус, который заключает в себе группу жаровых труб, расположенных в кольце, образованном между кожухом и составным узлом теплозащитного экрана. Камера сгорания с забором воздуха используется для процесса горения и охлаждения. Охлаждающий воздух необходим для изоляции компонентов от теплового излучения, предотвращения утечки горячих газов из газового потока и отвода тепла от узлов турбины.

Ключевые слова: камера сгорания, газовая турбина, воздушный поток.

1. Gas turbine air intake system

The function of the air intake systemis to provide air that is free of moisture, dirt, salt and turbulence, in sufficient quantities for the engine across its full operating range. A cascade bend enclosure is fitted in the air intake enclosure to ensure that the air flow from the intake passes to the compressor smoothly without causing turbulence. The intake bend is housed in an enclosure mounted on shock resisting mountings, the lower flange of the bend provides a seal around the intake flare and the upper flange forms a seal around the mouth of the enclosure to prevent the ingress of foreign bodies between the intake bend and intake wall. A splitter silencer is an aerofoil section, made from perforated aluminium used to minimize turbulence and reduce noise levels in the intake system. [1]

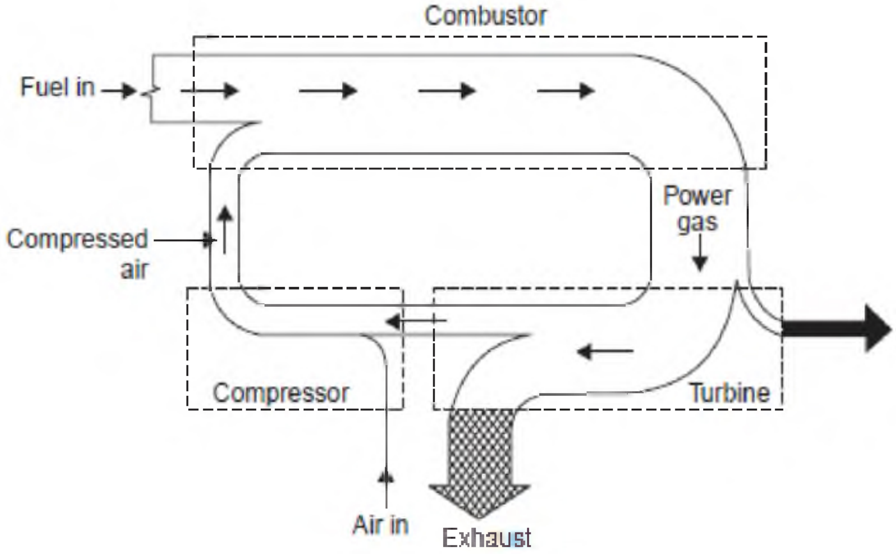

Figure 1 – Using air in gas turbine [7]

2. Air intake enclosure and ventilation system

The air intake enclosure forms the connection between the ship's air suction and the GTU (gas turbine unit), providing a casing for the cascade air intake bend. The cascade bend is fitted to provide airflow, free from turbulence, into the intake flare. The upper flange of the cascade bend forms a seal around the mouth of the enclosure to prevent the ingress of foreign bodies and allow structural movement of the module assembly. The lower flange is sealed at the intake flare. An inspection cover is fitted in the GTU enclosure providing access to the intake enclosure, and an access flap provides an entry to the cascade bend for intake inspections. In the turbine module, 2 ducts are fitted on the top of the enclosure to allow cooling and ventilation air to circulate through the enclosure, batch duct is lilted with a shutter which is held open by a spring loaded latch. When the fire extinguisher system is operated, a piston releases the latch and the shutters are closed with the assistance of springs.

They are reset by cable. In normal operation, an air How is maintained by an enclosure ventilation fan fitted on the exhaust side and operated either locally or from the local control panel. In an emergency, as example, if the exhaust fan is defective, operation of an emergency flap connects the exhaust duct to the transition duct at the gas turbine intake and the intake depression maintains an airflow sufficient to keep the module temperature within temperature limits in all operating conditions. Air supply to the module is a natural supply from either the upper deck of the cascade bend enclosure. [2]

3. Air bleed valve

At low engine rpm, the low pressure compressor works more efficiently than the high pressure compressor and there is a tendency for the air pressure to build up at the entry to the HP compressor. This can cause the air flow through the LP (low pressure) compressor to slow down or to stall completely, which will cause the compressor to surge, with the possibility of catastrophic results. This surging is prevented by releasing some of the air at the LP compressor discharge through the air bleed valve mounted on the intermediate casing. At higher rpm, the HP (high pressure) compressor achieves its full efficiency and can accept all of the air supplied by the LP compressor, so the air bleed valve is closed at high power. That the air bleed valve is needed to release excess air when HP compressor rpm is low in relation to LP compressor rpm. [3]

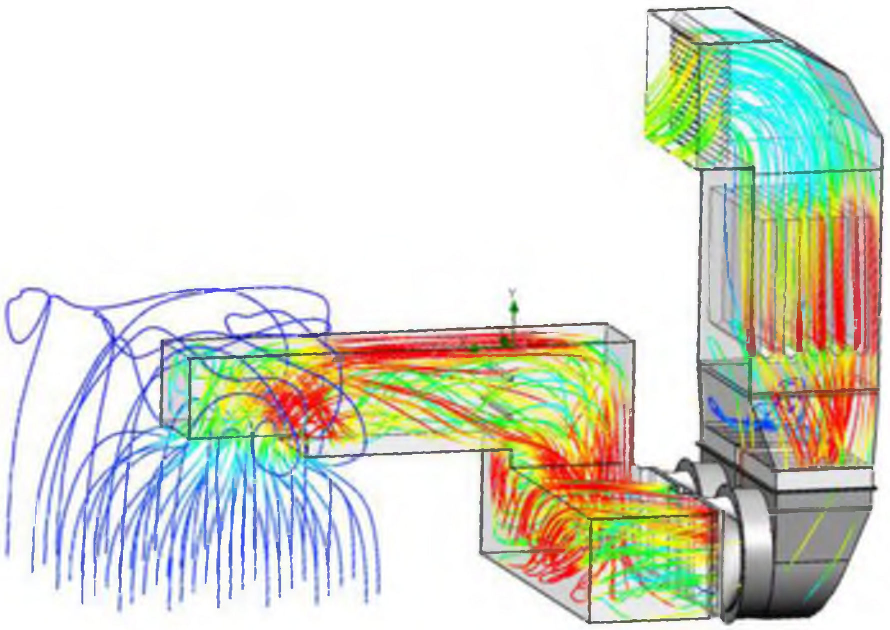

Figure 2 –Air intake system for cooling and combustion [9]

4. Combustion chamber cooling

The combustion casing is a cylindrical casing that encloses a group of 10 combustion chambers. A heat shield. Comprising lagging enclosed in dimpled stainless steel is attached to the outer casing in 2 segments joined by clips and spring fasteners. Two high energy plugs are mounted on the outer casing and projected into two opposite flame tubes. The heating assembly includes a swirler, which by imparting a rotary motion to the air entering the tube, has the effect of stabilizing and anchoring the flame. The flame tubes have rows of flanged holes, which admit air to mix with the fuel to complete combustion, cool the outer gas stream and prevent carbon forming. [4]

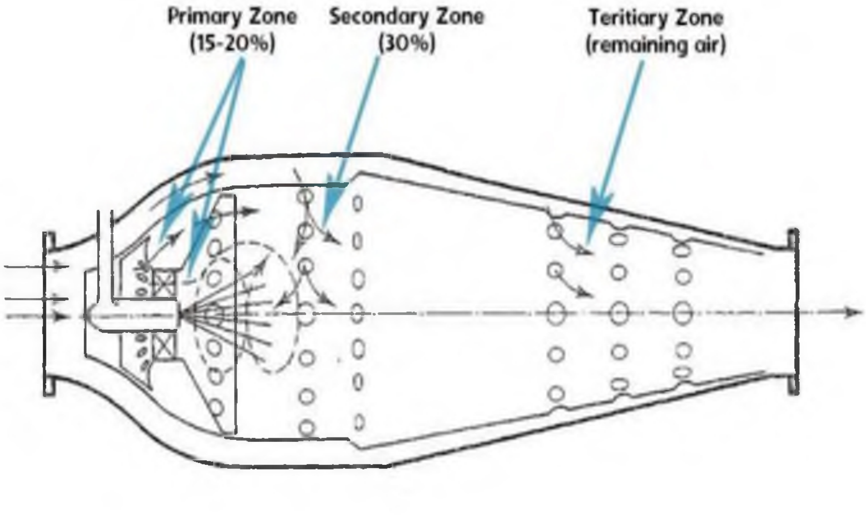

Figure 3 – Air split in the burning chamber [8]

Primary (15%) provides air for initial combustion and aids the atomization of the fuel. Secondary (10%) ensures complete combustion of the fuel and provides a layer of air between the flame tube to prevent flame impingement. Tertiary (75%) is heated by the combustion process to become the working fluid in the turbines and cools the products of combustion to an acceptable level for the turbines. Heating air is required for an anti-icing system to prevent ice build-up on the air intake, nose bullet, air intake guide vanes and the 'O' stage stator blades. A breathing or ventilation system is required to ventilation air/oil mist, separate the oil and exhaust the vent air into the main gas stream.

5. Power turbine disc cooling

After the inter-turbine bearing housing, the air passes inwards through a machined clearance on the outer periphery of the power turbine front stud shaft.

Some air passes through the rear seal of the entire turbine bearing housing and passes over the outer front face of the power turbine first stage disc, cooling it and exhausting into the gas stream over the blade roots. The majority continues to flow inwards into the hollow power turn shaft, cooling the front face of the first stage disc as it passes. Some of this air enters the inter-disc space and is proportioned by the inter-stage seal to cool the rear face of the first stage disc. The remainder then flows to the rear face of the second stage disc, cooling before exhausting into the main gas stream. [5]

Figure 4 – Rolls Royce Olympus gas turbine [6]

Fuel consumption for maximum load

$$\mathrm{B}_{100\%}=\frac{\mathrm{G}_{\mathrm{air}100\%}*(\mathrm{i}_{\mathrm{airout}100\%}-\mathrm{i}_{\mathrm{airin}100\%})}{\mathrm{Q}_{\mathrm{i}}*\eta_{\mathrm{T}100\%}+\mathrm{i}_{\mathrm{comb}100\%}+(\mathrm{L}_0*\mathrm{i}_{\mathrm{airiout}100\%}-\mathrm{L}_\mathrm{g}*\mathrm{i}_{\mathrm{g}100\%})}\left[\frac{\mathrm{Kg}}{\mathrm{h}}\right];\quad(1)$$

$$\mathrm{B}_{100\%}=984.66\left[\frac{\mathrm{Kg}}{\mathrm{h}}\right];$$

Effective air excess coefficient for maximum load

$$\alpha_{\mathrm{ef}100\%}=\frac{\mathrm{G}_{\mathrm{air}100\%}}{\mathrm{L}_0*\mathrm{B}_{100\%}};\quad(2)$$

$$\alpha_{\mathrm{ef}100\%}=4.91;$$

Effective air excess coefficient for primary air flow

$$\alpha_{\mathrm{Imax}}=\frac{\mathrm{Q}_\mathrm{i}*\eta_{\mathrm{T}50\%}+\mathrm{i}_{\mathrm{comb}50\%}+\mathrm{L}_0*\mathrm{i}_{\mathrm{air}900}-\mathrm{L}_\mathrm{g}*\mathrm{i}_{\mathrm{g}900}}{\mathrm{L}_0*(\mathrm{i}_{\mathrm{air}900}-\mathrm{i}_{\mathrm{airin}})};\quad(3)$$

$$\alpha_{\mathrm{Imax}}=4.69;$$

Secondary air flow

$$\mathrm{G}_{\mathrm{aerII}100\%}=\mathrm{G}_{\mathrm{air}100\%}-\mathrm{G}_{\mathrm{airI}100\%}\left[\frac{\mathrm{Kg}}{\mathrm{h}}\right],\quad(4)$$

$$\mathrm{G}_{\mathrm{airII}100\%}=47000\left[\frac{\mathrm{Kg}}{\mathrm{h}}\right];$$

where: B – fuel consumption

G – air consumption

i – air enthalpy

Q_i – fuel inferior caloric power

η – combustion chamber efficiency

L_g – gas flow after burning process

L_0 – air flow for burning process.

6. Calculation of air and fuel flow for a gas turbine

Table 1 – Olympus Rolls Royce gas turbine parameters

Parameters	**Value**	**Unit**
Gas generator mass	3040	[kg]
Low pressure compressor speed	6520	$[rpm]$
High pressure compressor speed	8000	$[rpm]$
Power turbine speed	5650	$[rpm]$
Effective power of gas turbine	18500	$[kW]$

7. Conclusions

Cooling air is required to insulate components against heat radiation to prevent leakage of hot gases from the gas stream and to dissipate heat from the turbine assemblies. For a good cooling the gas turbines must be optimized in terms of operation. Depending on the season and the navigation area, the operating parameters must be optimized according to the atmospheric conditions (air temperature, air humidity). After 1/3 of the gas turbine operating time, it was found that the engine power decreases by about 15% and this is due to the salt deposits on the compressor blades. That is why engines of this type have been equipped with devices for purifying the air and for cleaning the vanes. This also leads to better cooling and combustion. Through the improvements made to the basic elements of the engine (power turbine blades, compressor blades, regenerative recuperator and others) it has been achieved that the operation of these types of engines is superior to thermal engines used in extreme navigation areas (tropical and equatorial).

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ASPECTS OF CONTROLS PRINCIPLES IN SHIPS

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Following initial build, after refit or maintenance, it will usually be necessary to carry out tests of controlled systems, the control systems themselves and instruments within the control systems. The checks will usually be carried out by injecting input disturbances and watching how the output follows. Alternatively, load changes can be applied to disturb the system under control and the recovery curves observed. For example, the control of diesel generators can be checked by starting large equipment such as air-conditioning plant and observing the response of the engine speed and, at the switchboard, how well the voltage control systems function. In control engineering, it is frequently concerned with the graphical representation of time-varying signals.

Keywords: control, regulatory, machinery, signal

АНАЛИЗ ПРИНЦИПОВ УПРАВЛЕНИЯ НА СУДАХ

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После первоначальной сборки, после ремонта или технического обслуживания обычно необходимо провести испытания управляемых систем, самих систем управления и приборов в составе систем управления. Проверки обычно осуществляются путем введения входных возмущений и наблюдения за выходом. В качестве альтернативы можно использовать изменения нагрузки, чтобы нарушить равновесие управляемой системы и наблюдать кривые восстановления. Например, управление дизель-генераторами можно проверить, запустив энергоемкое оборудование, такое как установка кондиционирования воздуха, и наблюдая за реакцией скорости двигателя, а на распределительном щите — затем, насколько хорошо работают системы контроля напряжения. В технике управления это часто связано с графическим представлением изменяющихся во времени сигналов.

Ключевые слова: управление, регулирование, техника, сигнал.