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Aero Derivative Gas Turbine Preliminary Design – In Line with the Nigerian Industrialization Project

SHAIBU EROMOSELE
Department of Mechanical Engineering, University of Port Harcourt, Nigeria

Abstract- The Nigerian industrialization effort is highly desirable and would be more demanding in the nearest future. The only route to joining the league of developed nation is industrialization. There is the need to design and manufacture industrial equipment and accessories for both local and international application. The identified equipment is aero derivative gas turbine. It is an offshoot of aero engine, aircraft prime mover. The equipment is made up of compressor, combustor and the turbine (High pressure and free power turbines). It is applied in land and marine operations for power generation, gas compression and ship propulsion. The reference technology is LM2500 plus G5 for power generation. The study was premised on preliminary design. Aero derivative gas turbine operates on the principle of Brayton cycle. reference standard is International Standard Organization. The need for an aero derivative gas turbine was established, component parts, functional relationship and assembly methods were determined and established.

Keywords- industrialization, equipment, generation, compression, turbines, turbine

I. INTRODUCTION

In an emerging and developing economy like that of Nigeria, it is pertinent that one of the major contributors of sustainable economic growth; industrialization (to design and manufacture major machinery and auxiliary equipment) is given an unalloyed attention. The equipment of interest is an offshoot of LM2500+G5 (land and marine) aero derivative gas turbine. This is used for power generation in the power sector, power generation and gas compression in the oil and gas and marine sectors of the economy. This study shall be done on the premise of preliminary design (to determine a need, the equipment required, its major and sub components, their functions, relationship, assembly methods and scientific principle of operation)

The power house of every nation in the world today is the ability to harness her industrial potentials and capabilities. Technology transfer, research, development and sustainability are the basic input of industrialization effort that must be explored to the fullest by Nigeria as a nation. In addition to supporting and pioneering the effort of industrialization, enabling environment must be created by the Government for this to thrive.

A great number of gas turbines for stationary application operate with compression ratios in the range of 30:1. The aero derivative gas turbine is made up of the compressor, combustion chamber, and an expansion turbine. It operates on the Brayton thermodynamic cycle principle. It is a constant pressure open cycle heat engine (fuel is burned at constant pressure in the combustion chamber).

During the operation of aero derivative gas turbine, filtered atmospheric air (filtered by high efficiency and secondary filters) is taken into the compressor via the inlet plenum, directed into the compressor by the bell mouth, bullet nose and inlet guide vane, all mounted on the compressor. The compressor then compresses and increases the temperature and pressure of the inlet air. Fuel is added to the compressed air in the combustion chamber. The air-fuel mixture is ignited and expands through and drive the turbine to provide mechanical drive required to drive the generator or compressor shaft. Furthermore, mass of air is accelerated within the engine using a continuous-flow cycle. The process of ambient air entering into the inlet plenum and subjecting it to changes in temperature, pressure, and velocity is continuous mechanical activity.

Nigeria is a developing nation with a plan of becoming a developed nation. To achieve the aforementioned, all hands must be on deck and focused on developing and producing engineering and scientific equipment for local and international application (export). At the moment, Nigeria is totally dependent on imported aero derivative gas turbine for both power generation and the oil and gas industry. These are multimillion dollars and capital-intensive products that would metamorphose into foreign exchange savings, create employment opportunities, reduce over reliance on imported machinery equipment, while, systematical and reliably improving the Nigerian economy.

Furthermore, numerous aero derivative gas turbines are installed in Nigeria and many more to be installed in the future as the country power, oil and gas sectors businesses expand and diversify. The average cost of a new aero derivative gas turbine for a 30-to-40-megawatt capacity is currently between twenty-three and twenty-seven million dollars.

This work will increase literature in aero derivative gas turbine to be accessed by researchers and to be utilized by the appropriate industries for the purpose of aero derivative gas turbine design in Nigeria

II. LITERATURE REVIEW

Hans & Lutje (2025) presented that technology transfer is the transfer of knowledge and technicalities. It is a collection of input and output process, exchange of services within and across the society, industries, and nations. The three types of technology transfer are inside – out (from an organization that has the technology to another organization that requires the technology), outside – in (received by the organization in need of the technology from the organization that has the technology and then out – in – out. This is the combination of first and second types, a process where the two organizations have technological knowledge to transfer and to receive.

Further classification indicated a categorization of technology transfer into ten types. These include: a business with or without profit motive, commercial with profit motive, inner spill over model (to satisfy the need of functional system), science communication, research process preparation, research funding, exchange of personnel and technology, contract research, the incubator model, and finally the innovation ecosystem model.

Coral (2022) viewed technology transfer as an act that encourages investors, firms and industries to participate in technological development by sharing, accepting new technology, skill and embarking on research and development. Technology transfer has the collaborative tendency in technological advancement and social economic development. Technology transfer could be vertical (across different stages of product development), horizontal (technology sharing between different entities and manufacturers), internal (within the organization), external (between University technology transfer Office and firms), commercial (for the purpose of revenue generation), non-commercial (for societal benefit and others (international technology transfer, Government to industry technology transfer, industry to industry, reverse, forward and interactive technology transfer)

Ken et al (2017) opined that aero derivative gas turbines that are now being applied for stationary power are actually secondary product of turbo jet (that is to generate thrust by expelling hot and high velocity exhaust gases) and turbo shaft aircraft engine (that is generate mechanical power by converting the turbine power to mechanical energy via a shaft and accessory, like the helicopter shaft and rotor). Three very important characteristics of aero derivative gas turbines are that: they are lightweight in nature and thermally efficient, but more expensive than products designed and built solely for stationary applications.

According to Aeronautics guide (2023), aero derivative gas turbine engine converts chemical energy of compressed air and fuel mixture into heat energy in the combustion chamber. Turbine is classified as heat engine. The compressed air fuel mixture is converted to kinetic energy in the form of a high velocity stream of expanding gases. This kinetic energy is again transformed into mechanical energy as the gases rotate a series of turbine wheels to drive a compressor and its accessories. For turbo shaft engines, the expanding gases can also drive a second power turbine to drive a propeller or gearbox. The Brayton cycle (or constant pressure cycle) is the energy transformation cycle in a gas turbine engine with intake, compression, combustion, and exhaust stages. The four actions of intake, compression, combustion, and exhaust occur simultaneously and continuously. Therefore, there is continuous production of power by expanding gas inside the turbine engine. For continuous production of power output, air-fuel mixture is burnt in the combustor of the turbine engine continuously as indicated in Figures 2.1 and 2.2. In the intake stage, the gas turbine engine takes in ambient air into the engine via an inlet duct and into stage 1 of the compressor. The compressor stages are designed to increases air pressure and temperature. Combustion fuel is atomically sprayed by the fuel nozzle into the incoming airflow and ignited at the combustor for a continuous combustion process. Heat energy is continuously released in the process of combustion at relatively constant pressure.

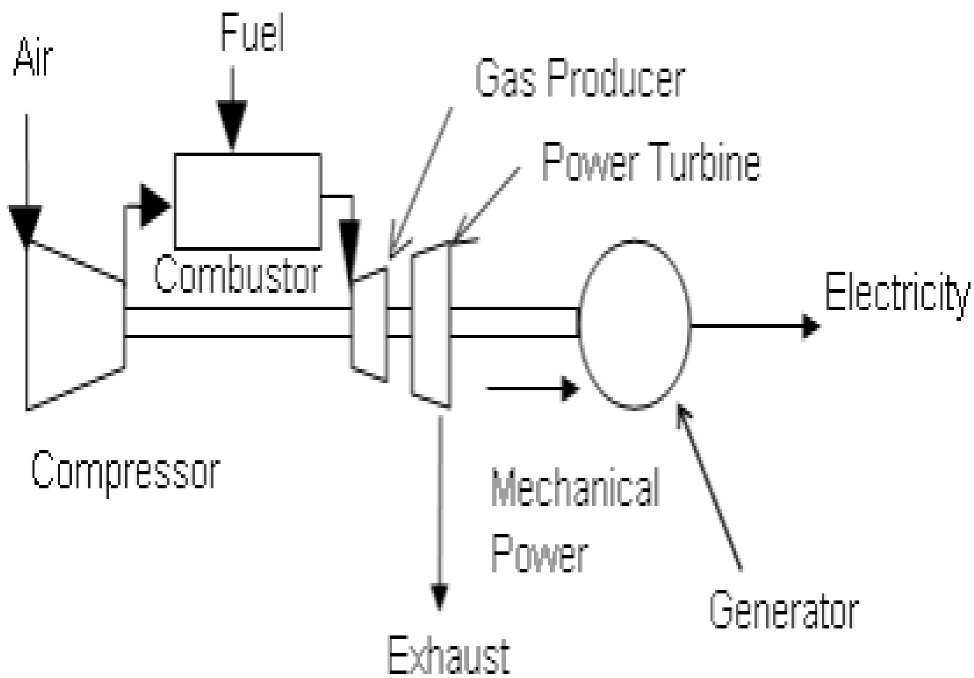

Figure 2.1: Gas Turbine sectional overview (Aeronautics guide 2023)

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Figure 2.2: Gas Turbine operational stages - intake, compression, combustion, and exhaust (Aeronautics guide 2023)

As exhaust gas exits the combustion chamber, it passes through the turbine where static air pressure drops, and air volume continues to increase, thus providing the required energy to drive the power turbine at relatively high velocity and pressure of the expanding gases. This is indicated in figure 2.3 where changes in pressure and volume during engine operation are illustrated. At point A indicate the ambient air condition before the compressor, with pressure increase and volume decrease as the air progresses into the compressor. Point B is the stage indicating the pressure and volume of air as it leaves the compressor. While, at point C, the volume of the gas mass experience expansion as heat is added with little or no change in pressure. Upon heating, the air expands and loses pressure as it flows through the turbine section to point D.

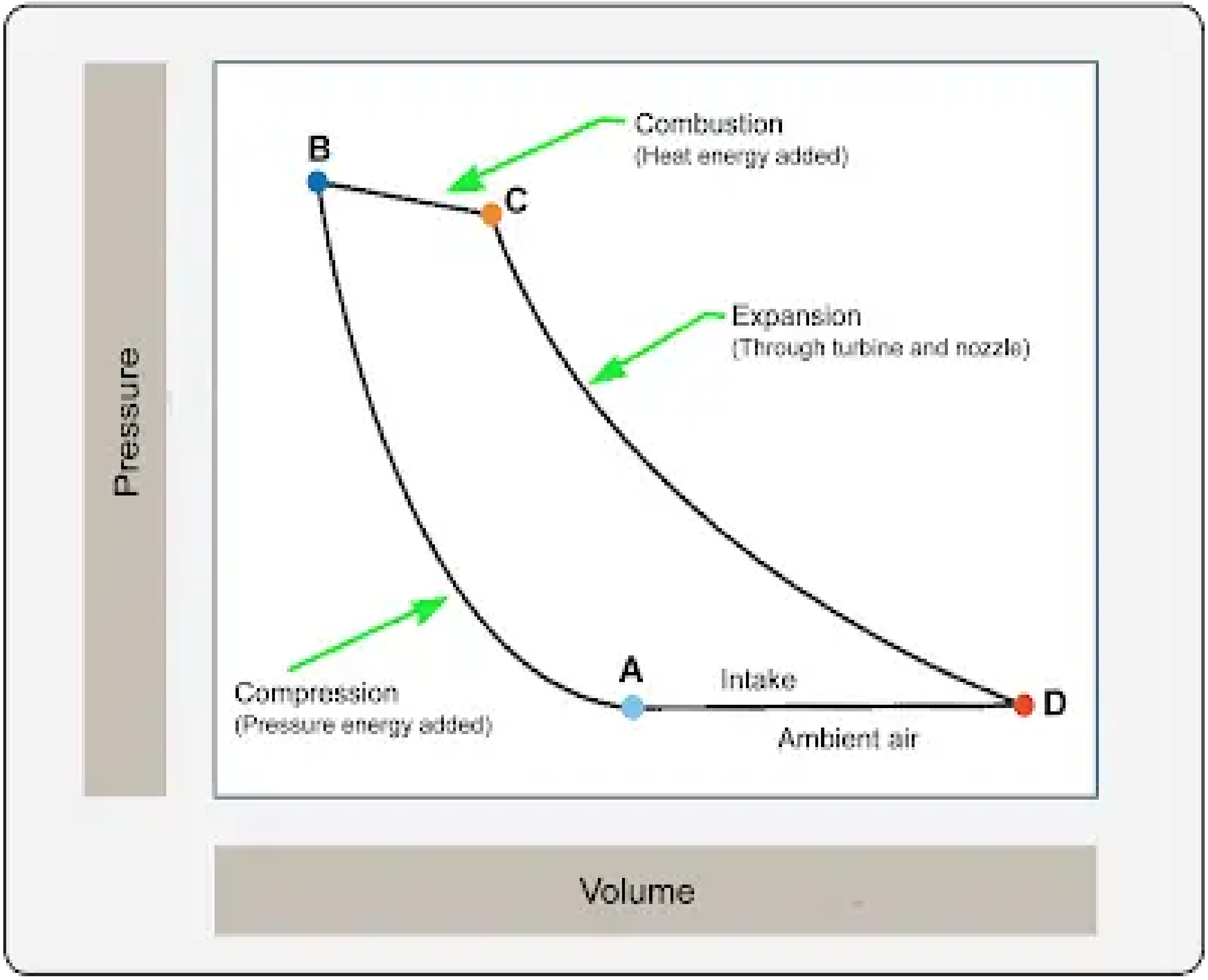

Figure 2.3: P-V diagram of a standard air Brayton cycle (Aeronautics guide 2023)

Rabiu (2022) presented that gas turbine design and operation are based on thermodynamic and Brayton Cycle principle, anchored on the dynamic relationship between pressure, temperature, entropy, and enthalpy. The first law of thermodynamics is applied to the air-standard Brayton cycle, with specific assumption that kinetic and potential energy remained unchanged during the cycle processes.

Brayton Cycle is represented in Figure 2.4 below in stages.

1-2: Isentropic compression (Air compressor).

3-4: Isentropic expansion (combustion products in turbine).

4-1: Constant pressure heat rejection (exhaust).

2s & 4s: These stages demonstrate ideal situation.2-3: Constant pressure heat-addition (compressed air with fuel in combustion chamber).

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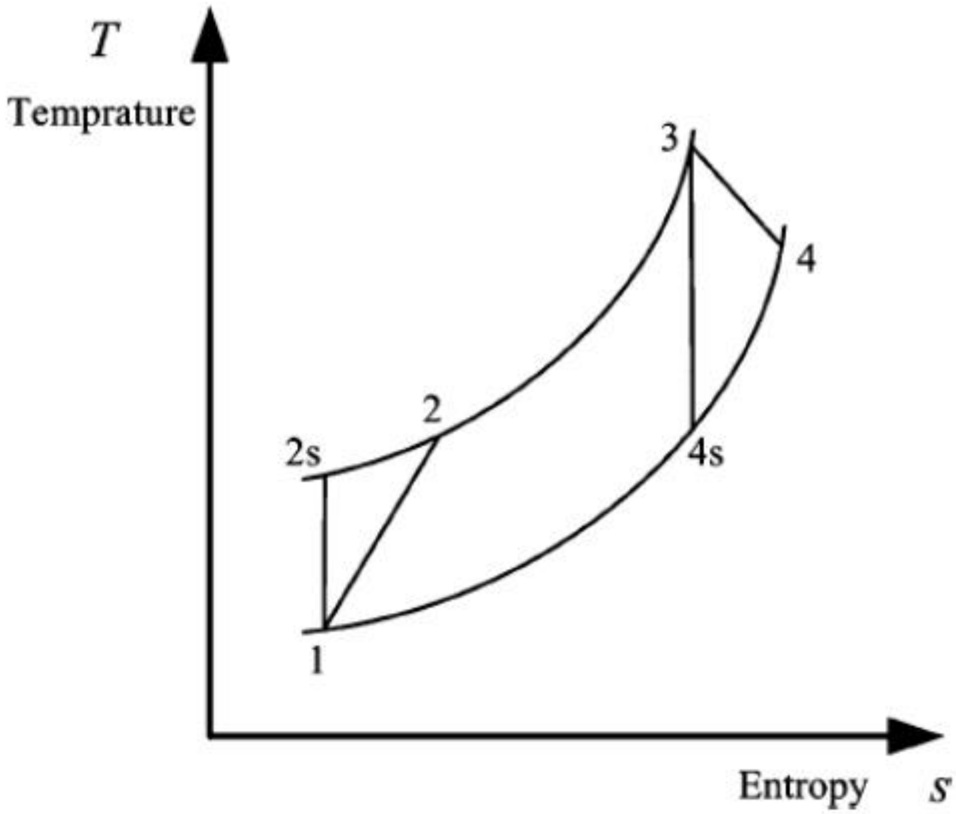

Figure 2.4: Ideal Brayton Cycle in Temperature-Entropy frames (Rabiu, 2022)

In an attempt to extend the ideal representation of gas turbine cycle to depict the actual operational gas turbine cycles applicable to industries, the cycles are categorized as; Simple cycle (20-43%), Regenerative cycle (30-45%) and Combine cycle (55-60%)

Simple cycle as shown in Figure 2.5a is highly flexible with low operating cost but constrained with poor thermal operational efficiency which is associated with exhaust gas discharge to atmosphere. The direct exhaust discharge could be prevented and utilized to improve the efficiency of the turbine cycle. This is achieved by preheating the compressor discharge air in the exchanger before reaching combustor as shown in Figure 2.5b. The cycle efficiency is also enhanced when gas exhaust is diverted to heat recovery steam generator (HRSG) to driver steam turbine or generate heat for plant heating processes. This process is known as combine cycle and can improve efficiency up to 60% (Rabiu, 2022)

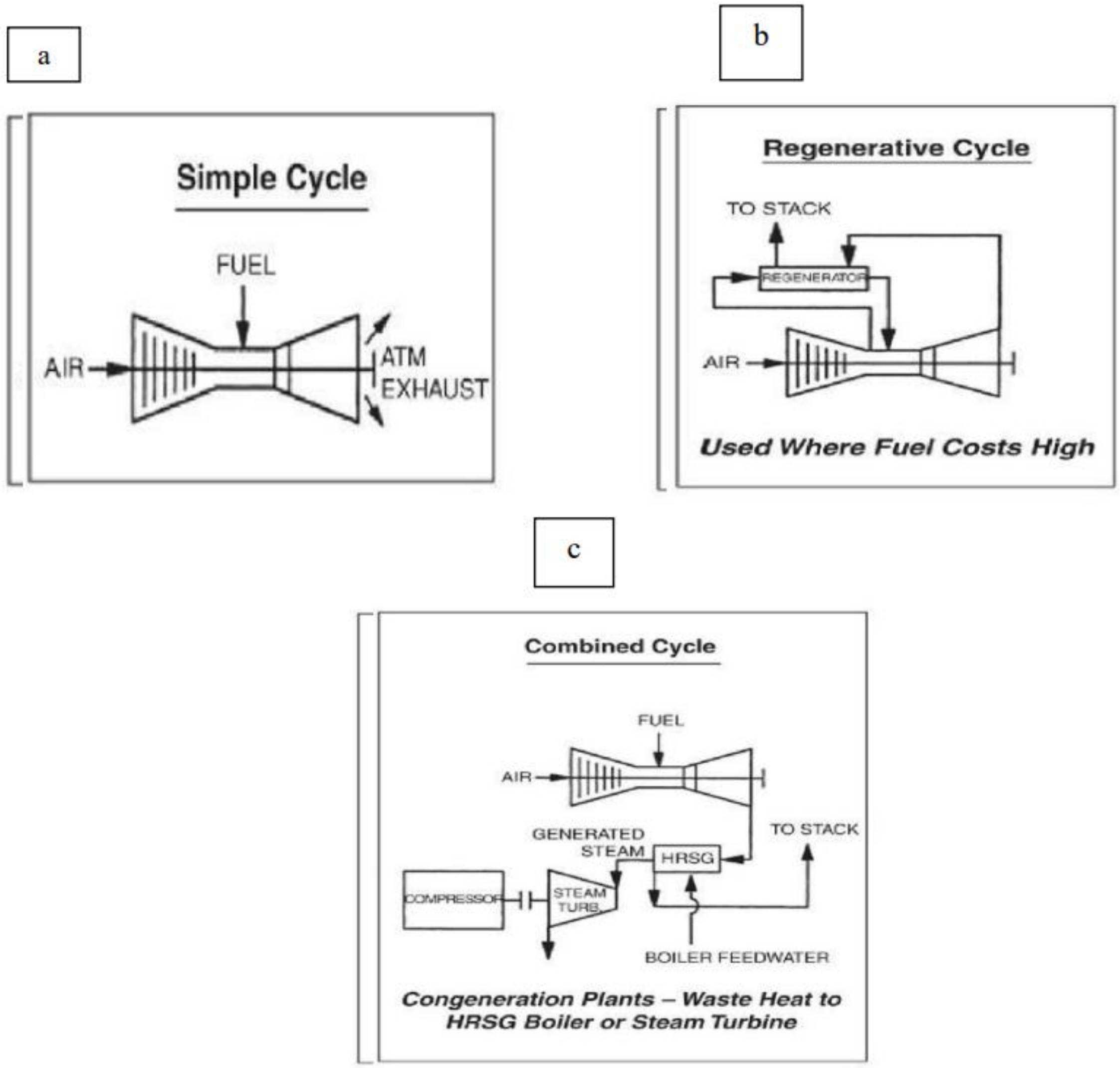

Figure 2.5: (a-c) Gas turbine Simple cycle, Gas Turbine regenerative cycle, and Gas Turbine combine cycle (Rabiu, 2022)

According to Badeer (2020), the aero derivative gas turbine has a distinctive feature of economic and operational advantage to the end user. The land and marine aero derivative gas turbine has power output of between thirteen and forty-seven megawatt. Its major components are the gas generator (compressor, combustor, high-pressure turbine), variable geometry for inlet guide and stator vanes, coated combustor dome and liner, air-cooled high-pressure turbine blading, uncooled power turbine blading, fully tip-shrouded power turbine rotor blading and an accessory gear box mounted on the gas generator.

The gas generator has single rotor high-pressure turbine aerodynamically coupled to the power turbine (high speed turbine with high velocity compressed flow connected to a low speed turbine power turbine). The LM2500+ G5 is an upgrade of LM2500 by the addition of zero stage to the compressor section of the gas generator, improvement of both high-pressure and power turbine materials design. The power turbine is of two models, one is six stage – low speed (3600 rpm) while, the other is 2 stage – high speed (up 6400 rpm operating speed).

Travis (2013) presented that aero derivative gas turbine used for land and marine operations by industries are offshoot of aircraft engine with unique characteristics of quick stat-up for emergency power generation, flexibility, light weight, smaller, high efficiency, simplified installation and maintenance. These gas turbines can be designed and installed for both electricity and heat generation, thereby raising its operating efficiency above 80% with output capacity of up to 65 mw.

The LM2500+ G5 aero derivative gas turbine is made up of 3 major components of the compressor (where air is compressed to higher pressure and temperature), combustion (where combustion process of compressed air fuel mixture is takes place) and finally, the turbine (where expansion of the burnt gas takes place and chemical energy is converted to mechanical energy as the expanding gases rotate the turbine blade and the rotor, thereby continuing the cycle.

Brandt *et al* (2020) opined that the first element of General Electric design philosophy is evolution (continuous improvement in quality, safety, reliability, availability resulting from research and development and feedback). Geometric scaling of both compressor and turbine is the second element of General Electric aero derivative gas turbine design philosophy (that is machine size can be increased or reduced, while simultaneously reducing or increasing other design and operating parameters of the machine like the rotational speed to produce an aerodynamically and mechanically similar product of compressors and turbines). Utilizing scaling help maintained geometric similarities with equivalent compressors and turbine resulting to constant temperature, pressure, blade angles, stresses and important cycle parameters (pressure ration and efficiency). If scale factors are defined as ration of diameters, shaft speed is inversely proportional to the ration, while linear dimension is directly proportional to the scale factor, the air flow and power vary with the square of the scale factor and weight vary with the cube of the scale factor, see table 2.1. The vibrating frequencies of blading relative to rotation speed and stress levels of scaled compressors and turbine are the same. So, scaling encourages maximum use of experience

Third element of General Electric design philosophies is thorough development (design analysis, quality manufacturing, testing and feedback from the field). The common materials used by General Electric in manufacturing are grey iron, nodular iron for casings, low alloy steel for compressor and turbine wheels which allow fabrication in most locations using foundry and forging technologies.

The thermodynamic principle of gas turbine operation cycle is Brayton cycle, with constant addition of heat energy, which is constant heat process. As seen in figure 2.6, atmospheric air is compressed from stage one to two, lower pressure and temperature to higher values at the compressor. Combustion takes place from stage two to three at constant heat in the combustor. Burned gas expansion takes place from stage three to four at the turbine and work is done.by the expanding gases on the turbine. From stage four to one, used gas is exhausted from the exhaust or used for other purposes in a combined cycle or combined heat process.

Table 2.1: Gas Turbine design geometric scaling (Bandt, 2020)

Ratio	0.5	1	2
Pressure	1	1	1
Efficiency	1	1	1
RPM	2	1	0.5
Velocities	1	1	1
Flow	0.25	1	4
Power	0.25	1	4
Weight	0.125	1	8
Stresses	1	1	1
Frequency	1	1	1
Tip speed	1	1	1

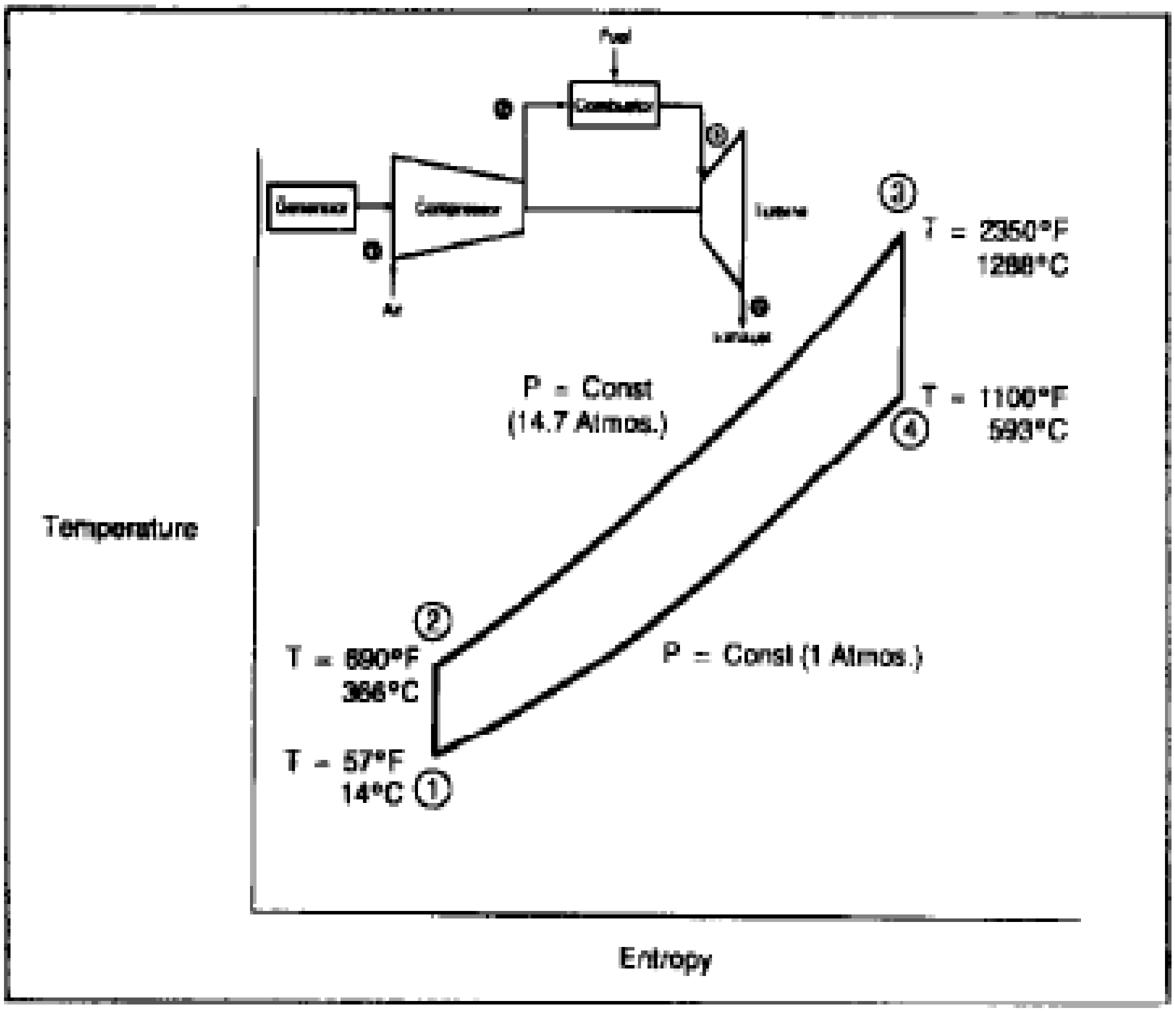

Figure 2.6: Brayton Cycle in Temperature-Entropy chart (Bandt, 2020)

Sagar (2019) presented that there was a considerable advantage in efficiency and power output of the turbine with double curvature radial blade design. This unique design is a blade shape curving in two directions along the blade length and in twisting or warping manner across its width. The design optimizes the aero dynamic performance by improving and managing air flow around the blade with improved efficiency and output. The double curvature radial blades are actually more expensive to manufacture, but lighter in weight and more efficient than the conventional blade. The article compared the optimized geometry with the conventional or initial geometry using computational fluid dynamics and finite element analysis techniques – FEA (a tool to predict a product reaction to vibrations, heat, fluid flow and other physical effects and is applicable in life sciences, aerospace, automotive, and consumer products) which indicated an improvement of six percent in total to static efficiency (ratio of ideal work output to actual work output). Stress analysis also indicated mechanical viability of the turbine comparing maximum stress to yield strength of the materials.

During the preliminary design of a radial turbine for gas compression or power generation, it is important to determine the output targets. For instance, 56 Kw turbine power output required for 110mm compressor or a 20 Kw turbine output required for power generator. The article however indicated that a 113mm radial turbine would meet this requirement. The second item to be determined is the preliminary or mean line design in order to have an overview of the turbine dimensions and its aerodynamic rotor performance. This mean line design is critical for a successful turbine design. It is pertinent to now determine the turbine design specifications after the output targets have been decided and thereafter the design.

Shuwei *et al* (2018) opined that one of the critical elements of aero derivative engine design is mathematical model. It is applicable during research, design, and development and monitoring during operation. Intelligent algorithms such as neural network, support vector machines are used in mapping inputs and outputs directly in aero engine modeling. This could be none- linear model with complex function relation and broad operation coverage or linear model.

The relationships among aero engine variables are complex and difficult to evaluate exact derivatives. Derivatives are involved in getting the Jacobean matrix of the component level model (CLM) and state-space model with the result calculated using finite difference approach. The paper proposed an exact derivative-based modeling method of aero engine, transforming the problem of derivative calculation to problem of differential calculation with a chain derivation method. This is to be executed according to the component level model. However, there was a time improvement of between 54% and 55% in both steady and transient states of the component level model when the proposed method was used.

The article reviewed conventional modeling methods, numerical difference method, the component level models and simulation of aero engine parameters. The component level modeling of aero engine is very popular in aero engine components design by modeling each component applying the principle of aerothermodynamics (aerodynamics and heat transfer study – using navier stokes equations) in setting and solving emerging co-operating equation (balance equation) to determine the required derivatives.

Christian *et al* (2025) presented that turbine blades and airfoil profile parameterization is an evolving research topic, considering the fact that the suction and compression sides of the blades differ in requirement and specification. Due to this further requirement and the need for optimization of parameterization of turbine and compressor blades, two main approaches of blade parameterization have been established. These approaches are engineering parameters - designing blades by applying standard engineering design principles and software to ensure design is done to standard, specification and fully optimized. The design can be referenced for future development and upgrade. The second approach to blade parameterization is free form deformation with high degree of blade design freedom by the deformation of existing blades.

The paper majored on engineering parameter for parametric blade geometry design using BladeGen and AutoCAD software. This design software has the capability of enhancing various blade specification, use of engineering parameters, production of even and smooth geometries with continuous curvature as desired, compatibility retention with AutoCAD software, design improvement, sensitivity to design variables and cost efficiency. BladeGen design approach is made up of four parts; profile construction into B-spline curves in a two-dimensional coordinate system, transfer the two-dimensional staggered profile into a three-dimensional coordinate system, a three-dimensional B-spline tensor product surface is bared by the three-dimensional profile and then generate fillets, cut blade region and off course linear transformation.

Blade angles and thickness resulting from preliminary aerodynamic codes are some of the descriptive parameters used by aerodynamic turbo machinery engineers to describe blade surface.

Bing *et al* (2020) opined that achieving required targets of a gas turbine engine performance in operation, availability, reliability, quality and safety is critical. One of the ways to achieve the aforementioned is by ensuring blade tip clearance is within range (radial distance between the rotor blade tip and the turbine casing). Larger blade tip clearance reduces the efficiency of the engine due excessive gap, while inadequate clearance could result to rubbing and damage to the engine. Considering the importance and critical nature of this activity, researchers are advancing blade tip clearance measuring technology. It is important to note that blade tip clearance measurement a difficult task to perform accurately during engine development and test period. Various blade tip clearance measuring methods like the probe method, tip timing method (a none destructive testing approach, pause modulation and also detect vibration), inductive method (measuring inductive variance in the planar spiral coil), microwave method, capacitive method (done by capturing variable capacitance formed between blade tip and sensor probe), optical fiber method, eddy current method (applying the principle of electromagnetic induction) and many more are now being utilized by manufacturers to solve this difficult requirement of gas turbine blade tip clearance measurement activity. It is obvious that these numerous turbine tip clearance measurement approach has their advantages and disadvantages. Their area of application or usage varies, depending on approach and the design of aero derivative gas turbine blade and casing. Among all the approach method, the capacitive method is the most popular due to its simplicity, robust nature, effectiveness and high temperature resistance. This is used by General Electric on The LM2500+ G5 aero derivative gas turbine.

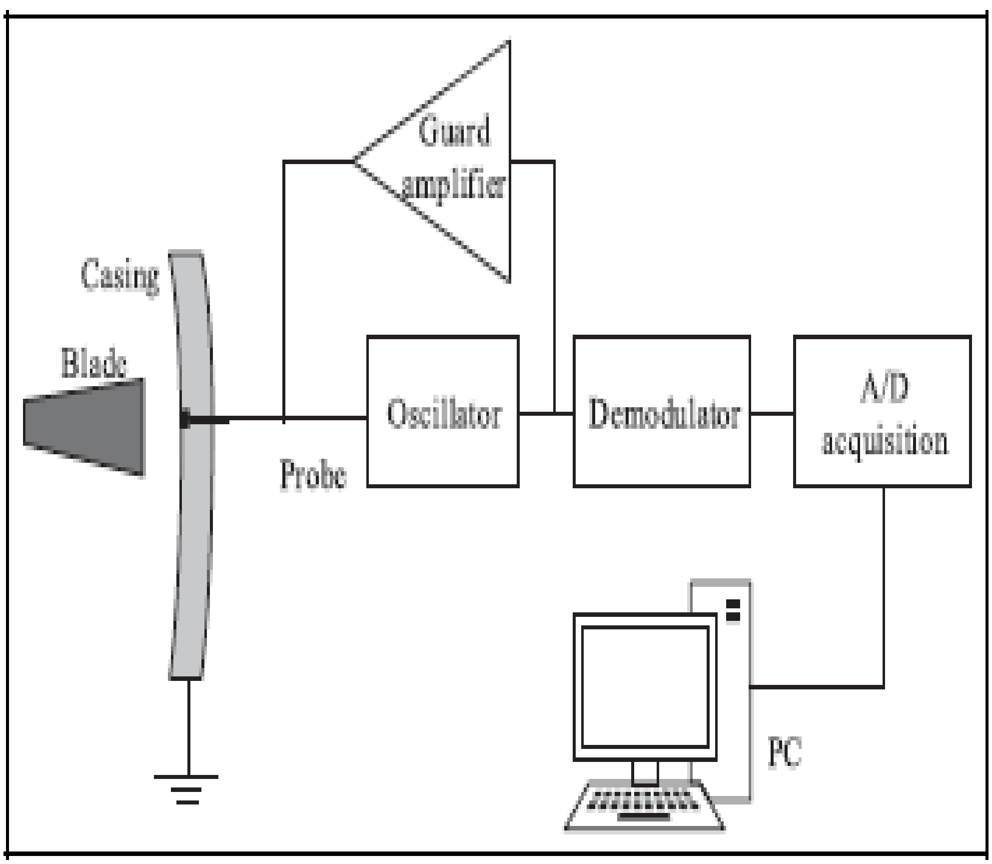

Figure 2.7: System diagram of capacitor method of blade tip clearance measurement of gas turbine engine (Bing, 2020)

Hang (2021) presented that a country's industrialization is key to her economic growth and sustainability. Aero derivative gas turbine manufacturing is a major contributor to country industrialization. It is used in both land and marine for power generation, propulsion and gas compression. The three major components of aero derivative gas turbine are the compressor, combustor and the turbine. The performance requirements of an aero derivative gas turbine are high power output, energy conservation and emission reduction. High thermal efficiency index of the aero derivative gas turbine is critical to achieving the aforementioned element and is dependent on the compressor stages. Therefore, a well-structured, coordinated and successful design of the compressor is critical to the performance of aero engine as it affect the thermal efficiency directly.

Aero derivative gas turbine compressor design is based on the meridional through flow-inverse problem calculation (streamline curvature method, through-flow matrix, finite element method and time marching method) in conjunction with numerical simulation analysis of the 3D viscous computational fluid dynamics, constituting a complete 3D aerodynamic design system. Multistage axial compressor stages and blades are quite enormous, present difficulty in matching flow angles between adjacent blades rows due to the voluminous design data to be considered. Thus, making the design a repeated iteration, this requires skillful approach and experience using computerized fluid dynamic technology.

However, the study centered on the direct manipulation of free form deformation approach and optimization algorithm, integrated into the multistage axial compressor aerodynamic system, based on the streamline curvature method. It is utilized to construct the parametric model of the compressor global geometry. The multi-island genetic algorithm is used to parameterized and optimize the inlet transition section, strut and other expansion section of the compressor.

Konstantinos (2019) presented that during aero derivative conceptual design, numerous constraints are considered. These constraints are applied in the optimizer environment, at the end of each design calculation sequence. Examples of such constraints are high-pressure compressor delivery temperatures, pressures, aviation regulations data, certification, materials and maintenance specifications. The optimization constraint helps ensure the feasibility of an aero engine design. It does not really do much to optimize the aero engine design. Engine design optimization depends largely on thoroughly selected data of merit applied in the optimization process. Some of the figures of merit are minimum block fuel (total quantity of fuel required for a journey), maintenance frequency, direct operating cost, emission, noise and many others.

In an attempt to determine optimal design, a Pareto front (80/20 rule) was constructed to visualize the region of optimal design. The constant block fuel line chat was plotted (specific fuel consumption rate against engine installed weight) using the air craft exchange rate for the base line design, the ISO-line defined the relationship between the aircraft weight and fuel consumption – a tradeoff relationship. The nacelle (engine structural enclosure) drag effect and non-linearity were however not considered for plot simplicity. During aero dynamic design optimization and in search of an acceptable engine design, evaluation is done continuously until reasonable progress is made. A design may be considered infeasible and dropped, if it fails to meet the constrain requirement set by the owner. Safety, quality and economic consideration are also major considerations during aero engine design; they depict sustainability, profitability, availability and reliability of the engine in question.

It is recommended that uncertainty (deterioration) be modeled into the design. The product introduction and life cycle management stages is classified into innovation/opportunity selection, concept design, detailed concept design, product realization, production, service support and finally disposal.

Ahmed (2017) reviewed numerous aero gas turbine engine generations, inventions and manufacturing activities. Some of the turbine engines reviewed are the turboprop (with gas turbine engine driving a propeller), turbo shaft engine (gas turbine engine driving a shaft), turbojet engine (gas turbine engine that expels the resulting hot mixture from the combustor to the atmosphere through nozzle to

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generate thrust), turbofan engine (gas turbine engine driving a fan to generate thrust), pulsejet engine (generate thrust through intermittent combustion and expansion – simple engine), industrial aero derivative gas turbine engine etc.

The industrial aero derivative gas turbine engine refers to the category of aero turbine engine that are not aircraft engine, but offshoot of aircraft engine. The aero derivative gas turbine engine is made of three major components of compressor, combustor and the turbine (high-pressure and low pressure). It is worthy of note that, unlike the aircraft engine, the aero derivative gas turbine engine has no restriction in weight and size. Its weight and size are driven by design requirement. The major manufacturers of aero derivative gas turbines are General Electric, Siemens, Solar turbines and Alstom. These engines are popular used in land and marine as prime movers for power generation, gas compression and fluid flow (pumps).

III. SYSTEM DESCRIPTION

The gas turbine initial rotor motion and motion up to design speed is provided by separate starter unit installed on the gas generator, until the expanding gases are able to keep the unit running. In between the initial rotor rotation and design speed, atmospheric air is taken into the gas turbine air compressor. The air is compressed via the various stages of the compressor. The compressed air is mixed up with fuel in the combustion chamber or combustor, where ignition and resulting gas expansion takes place. The expanding gases are passed through the gas turbine to provide the energy required to drive the turbine. The operation continues as turbine's shaft rotate and drive the compressor that is connected on the same shaft.

Aero gas turbine (aero engine) was originally designed as aircraft prime mover. The design concept was later adopted for power generation, oil, and gas industry by replacing the bypass fan with power turbine at the exhaust. The ADGT is made up of compressor module, combustor module and high-pressure turbine module. They are connected by one shaft. The coupled component is called Gas Generator (GTG). The other assembled component that is operated by the product of combustion from the Gas Generator to drives the end users is referred to as the Low-pressure power turbine (with a separate shaft). A very important part of aero derivative gas turbine design is the Foreign Object Damage (FOD) prevention. The FOD prevention and control screen is located in the inlet plenum and assembled to the gas generator compressor front frame. It is critical for a successful gas turbine engines operation, reliability and availability. FOD is debris of any form that is capable of damaging turbine engine internal components. FOD is a major potential hazard that is capable of bringing down gas engine for electrical generation, propulsion and aircraft. As a reflection of this criticality, affected personnel are trained and retrained on the topic foreign object exclusion in the turbine compartment and its environs.

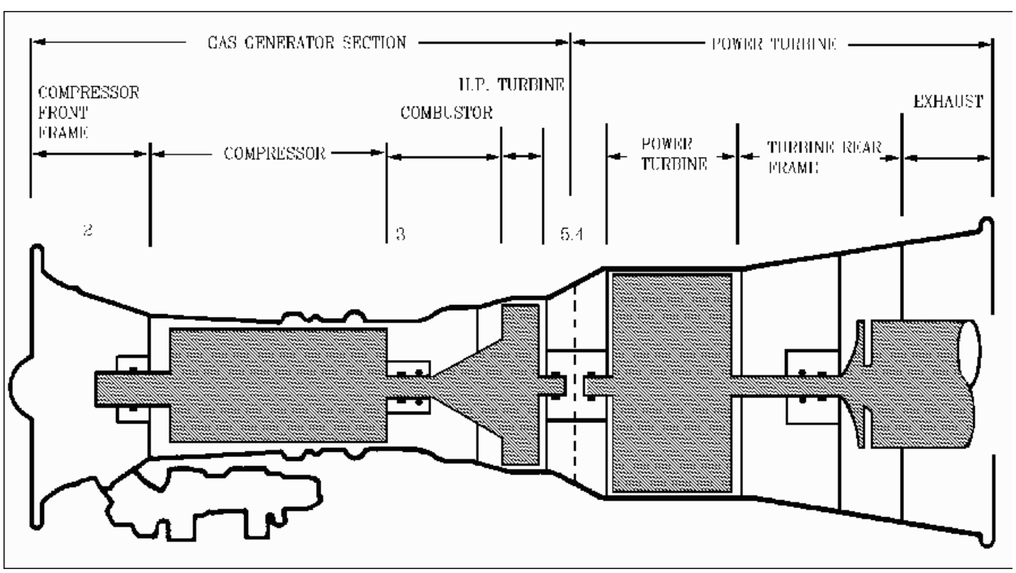

Figure: 3.1: Cross sectional view of an aero derivative gas turbine

The LM2500+ G5 is an updated version of LM2500 SAC which provides lower installed dollar per horsepower and life-cycle costs than The LM2500 SAC. It has power output of 36.8 MW, speed of between 3,050 to 6,450 rpm, exhaust temperature of 555^{0}C efficiency of 41%

ADGT Compressor stator casing houses one stage Inlet Guide Vanes (IGV), with six stages of Variable Stator Vanes (VSV) and 10 stages of Stationary Stator Vanes. The IGVs and stator vanes 1-6 have variable geometry. Blades angle of attack can be adjusted automatically to prevent compressor stall. Bleed air is extracted from the compressor to center the flame within the combustion liner internally in the engine and for other purposes.

The combustor is an annular type with 30 fuel nozzles and 2 spark igniters. The ignition system produces a high intensity spark to ignite the fuel/air mixture during the start sequence. The spark igniters are de-energized after start up. The pneumatic starter, fuel pump, lubrication oil pump, air separator and oil separator are installed on the accessory gearbox. The accessory drive assembly is driven through the compressor rotor shaft via the inlet gearbox, radial drive shaft, and transfer gearbox.

The LM2500+ G5 gas turbines drive the power generator via the high-speed flexible coupling and clutch. The high-pressure turbine on the GG is a two-stage turbine. The exhaust from the high-pressure turbine passes through a 5-stage low-pressure turbine which extracts the work required to drive the main reduction gear and ultimately the ship's propeller (when is for propulsion), power generator (when is designed for power generation) and gas compressor (when is designed for gas compression). The high-speed flexible coupling between the low-pressure gas turbine and the power generator or compressor absorbs both radial and axial misalignment between the FPT and power generator. LM2500 plus G5 module is totally enclosed to provide thermal and acoustic insulation. A top hatch and a side door or two side doors provide access to viewing of the engine. The module is shock mounted to reduce noise transmission.

The LM2500 is designed and configured to specifications, based on each user’s unique demands, environmental conditions and intended applications.

IV. DATA COLLECTION AND SOURCES

Aero derivative gas turbines for power generation and gas compression are designed according to customer requirement of power output and operating conditions. Data were determined and collated based on International Standard Organization (ISO) and site-specific requirement for the design of a low speed 40 MW aero derivative gas turbine required for power generation in Esan central local government of Edo state, Nigeria. Scientific and technical information were obtained from published industry research and aero Field Engineers and specialist interview.

V. PRELIMINARY DESIGN OF AERO DERIVATIVE GAS TURBINE

Preliminary Design of Gas Turbine Compressor

The aero derivative gas turbine axial compressor is located between stage one and two of the Brayton thermodynamic cycle. Atmospheric air (made up of 79% nitrogen, 20% oxygen and 1% other gases) is compressed to the required temperature and pressure in the compressor. The compressed air from the compressor is moved into the combustor where air fuel mixture and combustion take place. A lower temperature value of the compressed air into the combustor is recommendable to support higher aero derivative gas turbine power output

The standard LM2500 plus G5 singular annular combustor (SAC) has an aero derivative axial gas compressor of 17 stages, whereas the modeled aero derivative gas turbine has 18 stages (0 to 17), with an intercooler to reduce atmospheric air temperature into the compressor to between 15^{o}C. Other major components of the compressor are the compressor front frame assembly (CFF), compressor rare frame assembly (CRF), high-pressure compressor rotor, high-pressure compressor stator blade carrier, rotor blades, stator blades, six stage variable stator blades, inlet guard vanes, inlet duct, bullet nose, inlet gear box, transfer gear box, auxiliary gear box, starter and actuators.

High-pressure Compressor Rotor Assembly

Aero derivative gas turbine compressor shaft is one of the major components of the rotor and therefore the gas generator (GG). Design requirements of the shaft are mechanical integrity and reliability (strength to accommodate both axial and rotational load continuously as designed). The shaft ability to withstand high temperature, possess light weight, with acceptable production precision (quality product) are of critical importance. The shaft shall be a hollow spool structure, supported at the forward end by a roller bearing in the compressor front frame sump. The shaft shall house the tie rod that is screwed on the rear hub of the turbine wheels group, thereby keeping in contact with the front flange of the shaft. It also houses the slots (for rotor blade installation). The flange, hub and the wheels group shall be fastened together by a series of flange hub coupling screws. The material composition for rotor design and manufacturing shall be high strength titanium alloys, nickel based super alloys and hardened stainless steel.

High-pressure Compressor Stator.

The high-pressure compressor stator (HPCS) shall compose of two halves forward casing made of M-152 steel and two rear casing halves made up of Inconel 718. Each of the haves is split horizontally and all four pieces then bolted together. The HPCS shall house the compressor variable and fixed vanes and serve as the structural shell between the CFF and CRF. It shall contain one variable stage inlet guide vane, stator vanes of 18 stages (0-6 are variable using electro hydraulic system – stage zero shall be blisk design, an integral part of the rotor disk), and an outlet guide vane of one stage.

Compressor rear frame.

The compressor rear frame assembly shall consist of outer case, the struts, hub and the gas generator second sump, bearing both axial and radial loads. It shall be made of Inconel 718 material. It shall consist of an outer case, support igniter plugs, 30 fuel nozzles, fuel manifolds and high-pressure turbine nozzle support.

Preliminary Design of the Combustor

The combustor shall consist of cowl assembly (together with the CRF shall serves as diffuser and distributor of the compressor discharge air to the combustor – a machined ring, inner and outer cowl inlets welded to the inner and outer cowl wall), dome (a housing for 30 vortex inducing axial swirl cups, one at each fuel nozzle for the mixing of air and fuel for flame stabilization), inner liner and outer liner (series of overlapping rings joined together by welding and brazing with two sets of closely spaced holes helping to center flame and take in balance of combustion air). The design shall be a singular annular combustor SAC type of 30 nozzles. The combustor assembly shall be mounted on the CRF with 10 pins via the low temperature section of the cowl assembly. These pins center the cowl assembly in the diffuser passage and provide both radial and axial support.

The initial ignition of high energy sparks to ignite the air fuel mixture shall be provided by the igniter to commence combustion. The ignition system is made up of exciter, ignition lead and ignition plug. Combustion shall be self-sustaining after initial ignition provided by the igniter. The exciter shall generate the required voltage, the lead shall transmit and the plug shall generate the required spark.

Preliminary Design of the High-Pressure Turbine

The HPT shall be a two-stage air cooled (by convention) power turbine with a set of nozzle and blades at each stage. The HPT nozzle directs expanding gases from the combustor (working fluid at high velocity, pressure and design angle to the high-pressure turbine rotor blades, thereby converting the chemical energy of the working fluid to kinetic energy via the blades and turbine rotor. The 32-turbine nozzle segment in the assembly shall consist of nozzle support, nozzle vane (two) assembly, air baffle, pressure balance seal support and channel cover. Manufacturing shall be by casting and welding.

Preliminary Design of High-Pressure Turbine Rotor

The high-pressure turbine rotor shall have a conical forward shaft, conical rotor spacer, two disks with air cooled blades, retainers, thermal shield and an aft shaft. The function of the conical forward HPT shaft shall be to transmit energy to the high-pressure compressor rotor via the joint of the forward end of the shaft. Two air seals shall be attached to the forward end of the shaft for containment purpose of compressor

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discharge pressure at both ends. The two-cone shaped spacer shall be rabbeted between the turbine disks, they shall provide additional stability

Preliminary Design of Turbine Mid Frame Assembly (TMF)

The TMF shall be installed between the high-pressure power turbine stator flange and rear flange of the compressor outer case by bolting. The TMF shall support the end of the high-pressure turbine rotor on one side and the other side to support forward end of the PT rotor. The frame shall provide and enhance a smooth expanding fluid flow from HPT to the LPT. The frame hub shall be a one-piece casting to support the sump housing (of a double wall construction), stationary seals, inner liner support and PT stage one support nozzle. Bearing lubrication and seal pressurization piping shall be located within the frame struts.

Accessory Drive System

The accessory system shall be made of the inlet gear box (to be installed in the hub of compressor front frame to drive the compressor rotor – the inlet gearbox shall be driven by the radial drive shaft, its casing shall be made of aluminum and shall consist of shaft, bevel gears, bearing and oil jets, radial drive shaft (to be located in the six-o clock position of the GG compressor front frame. The radial drive shaft is a splined hollow shaft at both ends to transmit power between inlet gear box and the transfer gear box. Transfer gear box - to be located by the accessory gear box AGB with a set of right-angle bevel gears and a horizontal drive shaft to transmit power to and from the AGB and accessory gear box. The accessory gear box shall be made up of a 2-piece aluminum casings, gears, bearings, seals, oil nozzles and accessory adapters. It shall transmit power from the starter during start up to high-speed rotor through transfer gear box, radial shaft and inlet gear box). The plug-in concept shall be adopted as much as possible. The accessory gear box shall support the hydraulic starter, lubrication and scavenge pump, hydraulic pump, variable stator vane servo valve and other accessories

The lubrication and scavenge pump shall be a positive displacement vane pump with 6 elements. One element shall be for supply and the other five elements for lubrication scavenging, equipped with magnetic chip detection capabilities by resistance differential (drop in resistance across the detector). The lubrication and scavenge pump is mounted on the accessory gear box for the purpose of lubrication oil circulation and scavenging.

Air - Oil Separator is mounted on the AGB. Its main function is to curtain, control and separate vented oil air mixture from various vents to ensure vaporized oil is not discharged into the environment. It shall be made of a sheet metal impeller and cast aluminum housing. The sump vent air shall be discharged after passing through the separator. The oil shall be channeled through the holes in the segment of the impeller into the drain ports.

Preliminary Design of Free Power Turbine

This shall be a six-stage low speed power turbine with preliminary design speed target from 3000 to 3600 rpm. The power turbine shall be made up of power turbine rotor, power stator, power turbine rear frame and a coupling shaft.

Preliminary Design of Free Power Turbine Rotor

This shall be made up of rotor shaft, blades, seals, 6 disks (integral spacers) and spacers. The power turbine rotor shall be a six-stage low-pressure type. This shall be mounted on three bearings support (6R – roller bearing, 7B – ball bearing to carry the thrust load of the PT rotor, and 7R– roller bearing). Two shall be roller bearings and one ball bearing. The 7R– roller bearing shall bear the thrust load of the PT rotor.

Preliminary Design of Blades and Seals

The power turbine blades shall be a six-stage blade with interlocking tip shrouds for retention and stability. The blades shall also be retained in the disk by dovetail (a joining technique). There shall be seals between the disk spacers to minimize leakages. Corrosion protection coating shall be applied on the blades.

Power Turbine Stator

The six stages of blade shroud shall be installed on the power turbine stator. The first stage nozzle shall be installed on the turbine mid frame, while, stages two to six nozzles shall also be installed on the power turbine stator. The stator shall be a two horizontally split halves casing

The shrouds to be mounted on the casing channel would provide clearance seal. Insulations shall also be installed between nozzles, shroud and casing to protect the casing of high temperature gas stream.

Turbine Rear Frame

The power turbine rear frame is made up of an outer casing, eight equally and radially spaced struts and a single piece hub of steel casting. It supports the after end of the power turbine to form the exhaust flow path, the exhaust system, bearing housing (a one-piece casting of stainless-steel material) and oil air connections to and from the power turbine oil sump.

Exhaust duct

The exhaust duct shall be a fabricated horizontal and vertical structure – 90º to direct exhaust gases to the right channel. The fabrication is done by casting, welding, machining and fitting operation. It supports both axial and redial load of the power turbine. The exhaust duct shall have both inner and outer section to form the diffusing passage of the power turbine rear frame. Expansion joint shall be incorporated accommodate the expansion and contraction changes resulting from thermal changes of the metallic structure.

Flexible coupling shaft

The flexible coupling shaft shall consist of an adapter of Inconel 718 to mate with the turbine, flexible coupling, a distance piece and an aft adapter to be connected to the load. Its main function is to transmit energy from the power turbine to the power generator. The flexile coupling manages the axial and radial deflections between the aero derivative gas turbine and the power generator.

VI. CONCLUSION

Conclusively, preliminary design was done on major components of aero derivative gas turbine. The major components include compressor, combustor and turbine (high pressure and free power turbine). The detailed components parts were identified along with their functions and interrelationship. The assembly methods were identified. The referenced technology was LM2500+ G5 aero derivative gas turbine. Its thermodynamic principle of operation is Brayton cycle. That is constant addition of heat energy, constant heat process. Atmospheric air is compressed between stages one to seventeen in the referenced technology and from stage one to 18 in the modeled technology (level 1 to 2). Pressure and temperature values are increased at the compressor. Combustion takes place between level two and three at constant heat in the combustor. Expansion of burnt gases takes place from stage three to four at the turbine. Therefore, useful work is done by the expanding gases on the turbine. The hot gas is exhausted from stages four to one at the exhaust. The gases from exhaust could be used for other purposes in a combined cycle or combined heat process.

Looking into the future, the turbine design philosophies of evolution, geometric scaling and thorough development are key elements to achieving design targets with competitive advantage assured

REFERENCES

[1] Ken, D., Rick, T., James, W., & Anne, H (2017). Catalogue of Combined Heat Process (CHP) Technologies: *U.S. Environmental Protection Agency*. https://www.epa.gov/sites/default/files/2015

[2] Hans, H.G & Lutje, L (2025). On the divergence of function and service: Knowledge and technology transfer understood as the service process of social science system. *Journal of the knowledge economy. https://doi.org/10.1007/s13132-025-02646-4*

[3] Coral, N (2022). How technology is transferred. *Article on technology transfer*. Clarke modete. https://www.clarkemodet.com

[4] Badeer, G.H (2020). GE Aeroderivative Gas Turbines – *Design and Operating Features*. GE Power Systems. *GER-3695E. ■ (10/00)*

[5] Aeronautics guide (2023). Aircraft Gas Turbine Engine Operating Principles. Retrieved April 21, 2023, from <

https://www.aircraftsystemstech.com/p/turbine-engineoperating-principles.html

[6] Travis, R.D (2013). A case study on the Government role in energy technology innovation: *American Energy Innovation Council*. (202) 480 – 912.

[7] Brandt, D. E & Wesorick, R.R (2020). Gas Turbine design philosophy. *GE Industries and Power Systems*. GE – 3434D.

[8] Sagar, P & Kyle, J (2019). Applied Mathematical Modeling. *Design of Double Curvature Radial Blade for a Micro Gas Turbine*. 67(2019 529 – 548. www.elservier.com/locate/apm.

[9] Shuwei, P, Quihong, L & Haibo, Z (2018). An Exact Derivative Based Aero – Engine Modeling Method. *University of Aeronautics and Astronautics, Nanjing, China*.

[10] Christian, V, Martin, S, Jan, B, Georges, G & Andreas, P (2025). A Differentiated Geometry Blade Parameterization Methodology for Gas turbine. *Computer and Fluid.* www.elservier.com/locate/compfluid.

[11] Bing, Y, Hongwei, K, Enyu, S & Tianhong, Z (2020). A review of Blade Tip Clearance for Gas Turbine Engine. *Measurement and Control 2020.* Vol 53 (3-4) 339 357. DOI 10.1177/002029 4019877 514.

[12] Hang, X & Jiang, C (2021). Aerothermodynamic Optimal Design of a Multistage Axial Compressor in A Gas Turbine using Directly Manipulated Free – Form Deformation. *Case study in Thermal Engineering*. www.elservier.com/locate/csite.

[13] Konstatinos, G.K (2019). Gas Turbine Conceptual Design. *Cranfield University, School of Aerospace Transport and Manaufacturing, Propulsion Engineering Center*.

[14] Ahmed, F.E (2017). Aircraft Propulsion and GAS Turbine Engines. *Taylor & Francis Group*. http://taylorandfrancis.com.

[15] Rabiu, M. (2022) Predictive Maintenance of Critical Equipment for Floating Liquefied Natural Gas Liquefaction Process. *University of Plymouth Research Theses. Doi:* http://dx.doi.org/10.24382/750