THERMODYNAMIC ANALYSIS OF FRAME 9 E GAS TURBINE MODEL

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Abstract

The need for power generation has been increasing in our country and even around the world with the increase of population and other substantial needs. The power generation is majorly being done by steam power plants, thermal power plants, hydro power plants, gas turbine power plants and nuclear power plants. Of all these power plants gas turbine plant requires less initial investment.

The performance test on FRAME-9E gas turbine model has been conducted to find out the optimum pressure ratio, variation of turbine inlet temperature, and efficiency of the turbine at the test conditions by using diesel as a fuel at BHEL, Hyderabad.

The parameters affecting the performance of gas turbine are studied and performance characteristics of gas turbine are drawn. Effect of pressure ratio, air inlet temperature, turbine inlet temperature, compressor efficiency and turbine efficiency on performance of gas turbine is studied.

The performance test is conducted on MS 9001E model gas turbine at LANCO combined cycle power plant and thermal efficiency of the gas turbine and overall efficiency of combined cycle plant are calculated.

1 Introduction

The gas turbine is a source of conversion of heat into mechanical work by utilizing the hot products of combustion. The gas turbine is most satisfactory power developing unit among various means of power production due to its exceptional reliability, freedom from vibration and ability to produce large powers from units of comparatively small size and weights. The gas turbines are most widely used in power generation, military, industrials, rockets etc. the economics of power generation by gas turbine is proving more attractive in all parts of world due to its low cost reliability and flexibility in operation. Another outstanding feature of gas turbine plant is quick start and using variety of fuels from natural gas to residue oil or powdered coal.[1,2,3]

It's relatively low installation cost per KW installed capacity commended attention throughout the world as excellent source of peaking or emergency power. As manufactures increase the size and as the operators become impressed with the operating characteristics of gas turbine plant. The situation was further improved with the addition of regenerative cycle. With the addition of steam cycle in gas turbine cycle, the overall efficiency is further increased.[4,5,6]

1.1 Introduction to frame 9E gas turbine

The general Electric model 9001E package power plant is a combustion Gas Turbine 50 HZ electric generating unit with nominal base load rating of 110 MW. The heavy duty MS9001E gas turbine incorporates the most advanced gas turbine technology consistent with highly reliable and low maintenance service and field evaluation of machines with turbine inlet temperatures from 1000 to 1100^0 c with over 250 units.

Significant technological advances will allow the turbine inlet temperature to increase to 1085^0 c in the MS9001E, from the first MS9001E model operating at 1004^0C.These advances are in the compressor, turbine cooling and design of combustion hardware. The increased inlet temperature plus the higher pressure ratio and compressor air flow will result in an efficiency of 32.4 % (LHV) for a simple cycle power plant. A larger improvement in efficiency can be realized in waste heat recovery applications where, depending on the complexity of the steam cycle, an efficiency of at least 46% can be expected.

The 14 combustion chambers are canted and equally spaced around the periphery of the machine. The combustion liners are of the stronger and cooler slot cooled design at 1085^0c inlet temperatures .Each liner is approved combustion stability. The MS9001E has been design to burn a wide range of fuels from natural gas to heavy residuals and to keep the rates of ash buildup on the hot gas path parts at reasonable levels and to make the first stage nozzle cooling tolerant of ash deposits. The MS9001E has three turbine stages with the first and second stage is cooled. The first stage buckets coated for added corrosion. Protection and integral shroud tips on the second and third stage buckets.

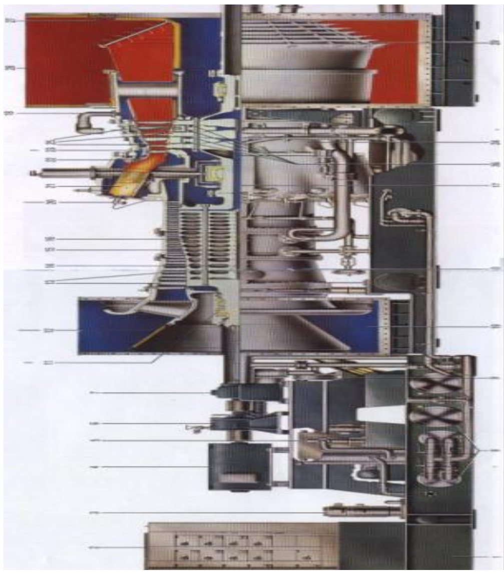


Fig 1.1 MS Frame 9E Gas turbine

1.3 SPECIFICATIONS OF MS 9001E

- Approximate size 12.5*5*5 in meters with 220 tons of weight
- Output 126.1 MW
- Heat Rate 10100 Btu/kWh (10653 kJ/kWh)
- pressure Ratio 12.6:1
- Mass Flow 418 kg/sec
- Turbine Speed 3000 rpm
- Exhaust Temperature 1009 °F (543 °C)

The model series 900IE gas turbine is shown in fig 1.1.it is a simple cycle prime mover which generally compromises the following components

- Turbine compartment
- Accessory compartment
- Control cab
- Inlet and exhaust system
- Generator excitation compartment
- CO_2 fire protection unit

1.4 TURBINE COMPARTMENT

The gas turbine has a 17 stage axial compressor. The compressor rotor consists of individual discs for each stage, and is connected by though bolts to the forward and after stub shafts. The turbine rotor consists of three stages, with one wheel for each bucket stage. The turbine rotor wheels are assembled by through bolts similar to the compressor, and with two spacer pieces; one between the second and third stage wheels. The entire rotor assembly is supported by three bearings.

1.5 ACCESSORY COMPARTMENT

The accessory compartment contains the mechanical and control elements necessary to allow the MS9001E gas turbine to be a self contained operational station. The major compartments located in the accessory compartment are the lubricating oil system and reservoir, lube oil cooler .starting means ,accessory gear, fuel system, turbine gauge panel, hydraulic system and atomizing air system, water system, as well as the motor control center and limit amp starter.

1.6 CONTROL COMPARTMENT

The control compartment contains the equipment needed to provide control, indication and protection functions. The control compartment is located forward of and in line with the necessary compartment and includes the turbine control panel, generator control panel, batteries and battery charger.

1.7 INLET AND EXHAUST SYSTEM

The inlet arrangement includes inlet air filters, silencing, ducting, and trash screens to protect the compressor from debris. It is mounted on the turbine base. The exhaust arrangement includes the ducting, silencing and necessary expansion joints It is mounted separately on its own base.

1.8 GENERATOR EXCITATION COMPARTMENT (G.E.C):

The G.E.C is a compartment mounted close to the generator collector end, and contains necessary relays, instrument PT's and CT's neutral grounding transformer and grounding resistor, lightning arrestors, surge capacitors, and contains the bus fed excitation regulators, excitation reactors and rectifiers, field flashing circuit breaker and field resistor Co_2 Fire protection unit. The bulk Co_2 storage unit is located off base near the gas turbine.

2 PERFORMANCE ANALYSIS OF MS 9001E GAS TURBINE

The performance test is conducted on MS 9001E gas turbine by using diesel as a fuel and following readings are taken.

N	actual speed	3047 RPM
$\mathbf{P_{amb}}$	ambient pressure	719.1 mm of Hg

APOC air pressure at outlet of compressor 7.868bar

ATOC	air temperature at outlet of Compressor	320.98 ^{0}C
FQ	fuel flow	145.365 LPM
VIP1	venturi # 1 inlet pressure	0.96 bar
VIP2	venturi # 2 inlet pressure	0.96 bar
VIP3	venturi # 3 inlet pressure	0.96 bar
VIP4	venturi # 4 inlet pressure	0.96 bar
VIP5	venturi # 5 inlet pressure	0.96 bar
VIP6	venturi # 6 inlet pressure	0.96 bar
VTP1	venturi # 1 throat pressure	288 mm of H_20
VTP2	venturi # 2 throat pressure	287.55mm of H_20
VTP3	venturi # 3 throat pressure	294.97mm of H_20
VTP4	venturi # 4 throat pressure	276.31mm of H_20
VTP5	venturi # 5 throat pressure	294.71mm of H_20
VTP6	venturi # 6 throat pressure	293.45mm of H_20
VIT1	venturi # 1 inlet air temperature	24 ^{0}c
VIT2	venturi # 2inlet air temperature	23.95 ^{0}c
VIT3	venturi # 3 inlet air temperature	23.925 ^{0}c
VIT4	venturi # 4 inlet air temperature	24 ^{0}c
VIT5	venturi # 5 inlet air temperature	23.55 ^{0}c
VIT6	venturi # 6 inlet air temperature	24.075 ^{0}c
APID	air pressure at inlet	0.93 bar atm
HGTE	hot gas temperature at exhaust	231.78 ^{0}c
HGPE	hot gas pressure at exhaust	723.92mm of Hg

Fig: 1.2 variation of thermal efficiency of gas turbine with air inlet temperature at different pressure ratios

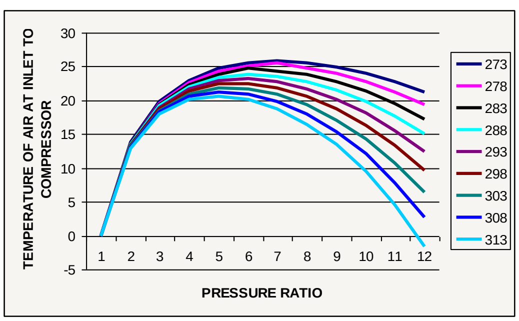
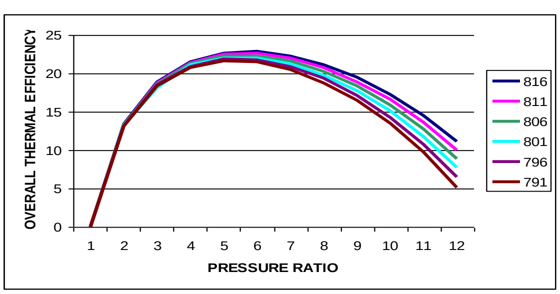


Fig: 1.3 variation of thermal efficiency of gas turbine with turbine inlet temperature at different pressure ratios



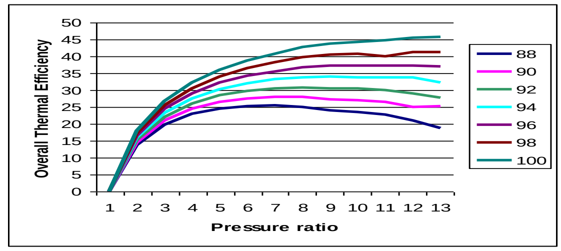


Fig: 1.4 variation of thermal efficiency of gas turbine with air inlet temperature at different pressure ratios

2.1 Combined cycle power plants &heat recovery and steam generation

The plant has rated output 351.2 MW and will be suitable for base load operations. The power plant is erected at Kondapalli, Krishna District, Andhra Pradesh, And India.

The plant has comprise two gas turbines, two HRSG (heat recovery steam generation) systems with horizontal natural circulation and triple pressure STEAM TURBINE.

The plant is designed as a base load system for operation at a design ambient temperature of 32 ^{0}c with possibility of daily stop or weekly stand still. The **GT/HRSG** start-up is temperature controlled. Each system stage consists of an economizer, evaporator and super heater. The feed water is heated approximately to boiling temperature in the economizer and feed into drum. The drum water is feed into the evaporator, where a portion is evaporated. The resulting water steam mixture returns to the drum where separators separate it. The separated saturated steam is fed to the super heater and is heated to main steam temperature. The condensate pressure-heater heats feed water for high, medium and low pressure steam stages.

2.2 Overall efficiency of the combined cycled plant

$\boldsymbol{\eta}_{\textbf{overall}}$ = ({total output from the gas turbines}+{output from steam turbine})/total heat supplied to the gas turbines

Total output from the gas turbines

=2 x output from the each gas turbine

= 2 x 104.036 =208.072MW

Total heat supplied to the gas turbines:

= 2x352.764 = 705.528MW

$$\eta_{\text{overall}} = \frac{208.072+118.617}{705.528} = 46.30\%$$

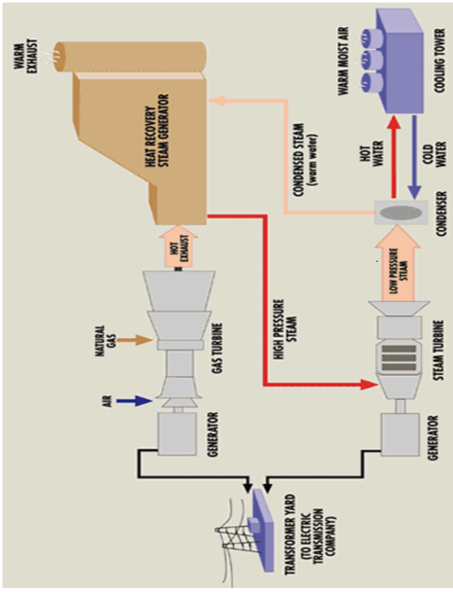


Fig 1.5 Combined cycle power plant

Conclusions

By performing various tests on the MS 9001E gas turbine, its initial starting troubles, oil leakage problems and vibrations are observed. The performance parameters affecting the performance of the gas turbines are compressor air inlet temperature, pressure ratio gas turbine inlet temperature and Adiabatic efficiencies of compressor and turbine.

In the present work, the performance test is conducted on 126MW MS9001E GAS TURBINE. The thermal efficiency of the gas turbine is calculated using diesel and natural gas as fuels.

As the air inlet temperature decreases, thermal efficiency of gas turbine is increasing at the given pressure ratio. At the given air inlet temperature (T1= 288 K), the thermal efficiency of the gas turbine is increases with pressure ratio up to 6. Beyond this pressure ratio thermal efficiency is decreasing due to increase in compressor work input. At the optimum pressure ratio 6 the maximum possible thermal efficiency is 23.81%

As the turbine inlet temperature increases, thermal efficiency of gas turbine is increasing at the given pressure ratio. At the given turbine inlet temperature (T3= 811 K), the thermal efficiency of the gas turbine is increases with pressure ratio up to 6.

Beyond this pressure ratio thermal efficiency is decreasing due to increase in compressor work input. At the optimum pressure ratio 6 the maximum possible thermal efficiency is 22.57%.

At the test conditions Adiabatic efficiency of compressor is 90.28%, air inlet temperature is 297.12 K, turbine inlet temperature is 811K, and thermal efficiency of gas turbine is increasing with Adiabatic efficiency of turbine.

If the Adiabatic efficiency of turbine is increased to 91% thermal efficiency of gas turbine is 26.58%.

By reducing the heat losses at the gas turbine it is possible to maintain adiabatic efficiency of turbine up to 91%.From the above analysis, thermal efficiency of gas turbine is increased by 5% with increasing the adiabatic efficiency.

The performance test is conducted on MS 9001E gas turbine at LANCO combined cycle power plant using natural gas as fuel, the combined cycle thermal efficiency of the plant is 46.30%.

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