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MECHANICAL RUN TEST OF STEAM TURBINE

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Abstract – Steam turbines provide a means of converting saturated, superheated, or supercritical steam from boilers or heat recovery steam generators (HRSG) into rotational torque and power The steam generated is of high temperature and high pressure. The temperature is often in the 450 to 540 degrees centigrade range. The pressure ranges between 60 and 120 bars. Standard Turbines from BHEL operate on 50% reaction principle and are therefore fitted with reaction balding, preceded by a single row impulse wheel as governing stage. Consequently steam turbines are utilized to drive a variety of equipment types of numerous sizes and speeds in just about every industry segment including power generation, pulp and paper, iron and steel, combined heat and power, and chemical, oil and gas industries. As testing is a very important aspect of production and is a must for reliable products and also improvement of products. Every department has its own Quality Circle which always thrives to increase the productivity of their department and hence help in increasing the profits of the firm. The project describes latest advancements used for evaluating and testing the performance of steam turbine like calibration of servomotor, calibration of pressure gauge and transmitter, calibration of pressure control valve and mechanical run test.

Key Words: Pressure Gauge, Transmitter, Contract Bearings, Couplings, Bearing Lube Oil.

1. INTRODUCTION

A steam turbine is a prime mover which converts heat energy into mechanical energy In a conventional steam turbines cycle, water is used as the working fluid. The water is heated in a boiler by burning fuel. It evaporates into steam which is expanded in a turbine where mechanical power is generated. The steam generated is of high temperature and high pressure. The temperature is often in the 450 to 540 degrees centigrade range. The pressure ranges between 60 and 120 bars. Most power plants use coal, natural gas, oil or a nuclear reactor to create steam. The steam runs through a huge and very carefully designed multi-stage turbine to spin an output shaft that drives the plant's generator. Steam turbines are devices which convert the energy stored in steam into rotational mechanical energy. These machines are widely used for the generation of electricity in a number of different cycles, such as Rankin cycle ,Reheat cycle, Regenerative cycle, Combined cycle, The steam turbine may consist of several stages. Each stage can be described by analyzing the expansion of steam from a higher pressure to a lower pressure. The steam may be wet, dry saturated or superheated.

1.1 Rankin Cycle

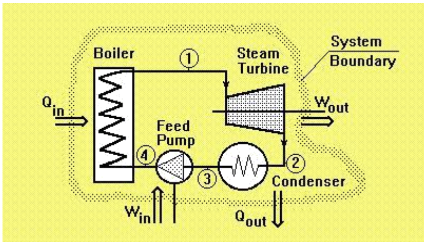

Fig 1.1 Block diagram of Rankin cycle

Consider the steam turbine shown in the cycle above. The output power of the turbine at steady flow condition is:P = m (h1-h2)Where m is the mass flow of the steam through the turbine and h1 and h2 are specific enthalpy of the steam at inlet respective outlet of the turbine.

1.2 Towards Higher Efficiency

Super critical technology advances aiming for 50 percent efficiency, Combined Heat and Power for low cost, more flexibility

1.3. Compounding Of Steam Turbines

Steam jet does maximum work with good economy when the blade speed is just half the steam speed. Due to very large rate of expansion, the steam leaves the nozzle at a very high velocity (Supersonic, since the pressure ratio exceeds the critical pressure ratio and the nozzle thus used is Converging – Diverging) of about 1000 m/sec. Even though the rotor diameters are kept fairly small the rotational speed of 30000 rpm may be obtained. Such high speeds can be used to drive the machines only with a large reduction gearing arrangement.

1.4. TOWARDS HIGHER EFFICIENCY

More efforts are being made to improve the efficiency of steam turbines. Super critical technology advances aiming for 50 percent efficiency. Renovating and upgrading for more value for money. Combined Heat and Power for low cost, more flexibility. Steam turbines in Combined Cycle, a new market Clean coal technologies FBC, PFBC, IGCC etc to improve the overall Efficiency and to reduce the pollution level.

1.5 COMPOUNDING OF STEAM TURBINES

Steam jet does maximum work with good economy when the blade speed is just half the steam speed. Due to very large rate of expansion, the steam leaves the nozzle at a very high velocity (Supersonic, since the pressure ratio exceeds the critical pressure ratio and the nozzle thus used is Converging – Diverging) of about 1000 m/sec. Even though the rotor diameters are kept fairly small the rotational speed of 30000 rpm may be obtained. Such high speeds can be used to drive the machines only with a large reduction gearing arrangement. In actual De-Laval turbine the velocity of steam leaving the blade is also quite appreciable resulting in energy loss. This amount to as high as 10-12 percent of the steam.

2 GOVERNING SYSTEMS 2

Governing system can be defined as a combination of devices and mechanisms which sense speed and power deviations and convert them to a servomotor stroke or gate position signal. Governing system is an important control system in the power plant as it regulates the turbine speed, power and participates in the grid frequency regulation. For starting, loading governing system is the main operator interface. Steady state and dynamic performance of the power system depends on the power plant response capabilities in which governing system plays a key role. The main purpose of the governing system is to maintain Constant speed at variable loads. Constant speed at varying steam inlet parameters. Constant speed at varying extractions and exhaust steam parameters/conditions.

2.1 WOODWARD GOVERNOR

The 505E is a 32-Bit microprocessor-based control designed to control single extraction /admission, or admission steam turbines. The 505E is field programmable, which allows a single design to be used in many different control applications and reduces both cost and delivery time. It uses menu driven software to instruct site engineers on programming the control to a specific generator or mechanical drive application. The 505E can be configured to operate as a stand-alone unit or in conjunction with plant's Distributed Control System.

2.2 OPERATOR CONTROL PANEL

The 505E is a field configurable steam turbine control and operator control panel (OCP) integrated into one package. A comprehensive operator control panel, including a two-line (24 characters each) display, and a set of 30 keys is located on the 505E's front panel. This OCP is used to configure the 505E, make On-Line program adjustments, and operate the turbine/system. Easy to follow instructions are presented in English through the OCP's two-line display and operators can view actual and set point values from the same screen.

2.3 TURBINE CONTROL PARAMETERS

The 505E interfaces with two control valves (HP & LP) to control two parameters and limit an additional parameter, if desired. These two controlled parameters are typically speed (or load) and extraction/admission pressure (or flow), however, the 505E could be utilized to control or limit: turbine inlet pressure or flow, exhaust (back) pressure or flow, first stage pressure, generator power output, plant import and/or export levels, compressor inlet or discharge pressure or flow, unit/plant frequency, process temperature, or any other turbine related process parameter.

2.4 COMMUNICATIONS

Communicate directly with plant Distributed Control Systems and/or CRT based operator control panels, through two Modules communication ports. These ports support RS-232, RS-422, or RS-485 communications using ASCII or RTU MODBUS transmission protocols. Communications between the 505E and a plant DCS can also be performed through hardwired connections. Since all 505E PID set points can be controlled through analog input signals, interface resolution and control is not sacrificed.

3 PERFORMANCE TESTING 3

The control of turbine with a governor is essential; as turbine needs to be run up slowly to prevent damage and some applications require precise speed control. Uncontrolled acceleration of the turbine rotor cam lead to an over speed trip, which causes the nozzle valves that control the flow of steam to the turbine to close. If this fails then the turbine may continue accelerating until it breaks apart, often catastrophically. Turbines are expensive to make, requiring precision manufacture and special quality materials. When the unit is new or has just been installed, tests are conducted to establish the efficiency or heat rate to ensure guarantee levels have been reached. These tests may be undertaken at various loads conditions depending upon the guarantee at different steam conditions. As the unit ages and deterioration occurs, the unit may be tested to determine both the extent of deterioration and to identify areas where this deterioration has occurred so that corrective action can be planned. These performance tests should be run in strict accordance with the test code to minimize test errors to the greatest extent possible. A major consideration with inefficient operation is identifying and quantifying the source of losses. Output test can help establish the magnitude of such losses, but the determination of their source and individual magnitudes is often difficult and detailed steam path audit is required to quantify and assist plant staff in maintenance decisions. Once the losses have been identified and their magnitude quantified, a financial penalty can be assigned to them. It then becomes easier to make replacement/repair/accept-as-is decisions based on fuel cost, predicted load factors, and other characteristics of the unit operation. There are also considerations related to the availability of replacement parts, special tools, and skills that may be necessary to implement the corrective actions. Each of these must be fully evaluated by operators in determining the most cost-effective approach for correction and return to service, plus the need and advisability of taking corrective action.

3.1 PURPOSE OF PERFORMANCE TESTING

The level of efficiency at which a steam turbine-generator operates is of considerable importance to the owner as this reflects the fuel costs he must pay for the energy generated.

Efficiency is important in the new unit and then the rate over which this varies or deteriorates during the unit's operating life. At the completion of erection or installation and when the unit has been commissioned, a performance acceptance test is often run. The primary objective of this test is to measure the energy conversion efficiency level and compare this test or measured value to that guaranteed by the supplier. The comparison is made for both heat rate and capacity. A performance test can also have the secondary objective of providing meaningful information to the manufacturer regarding the performance level of a particular section of the unit where design innovation has occurred. Such tests can also be designed to provide information about a particular component within a section. One very important aspect of performance testing is that such test enables a manufacturer to demonstrate that the unit will meet the guaranteed levels of performance on which the unit was sold. These results will also enable the purchasers to accumulate information regarding the probabilities of various manufacturers achieving guaranteed performance. This information will enable the owner to asses more realistically the heat rates being offered on future units and allow a better assessment in evaluations for subsequent capacity purchases. Shown as fig is a shotgun plot of test results without any adjustment for testing margin or other factor for one manufacturer. This plot makes a comparison of the guaranteed to actual test-determined values of heat rate to the guaranteed level. The tests were conducted according to the ASME PTC-6 Power Test Code for Steam Turbines. Therefore, a major requirement of any performance test is to accurately measure these parameters, both the primary values and the secondary effects which act to influence these primary values. Thermal power is measured by pressure and temperature, flow by metering and power by measurement of electrical power output. After testing and measurement of the performance values, it is necessary to make certain corrections for the steam-cycle conditions and the performance of equipment that forms part of the thermal power conversion cycle but is not part of the steam turbine generator supply. This equipment can comprise pumps, motors, heaters, or other heat transfer equipment. To make this correction will require either careful determination of their individual performance as part of the test, and then correction to reflect their true performance or their careful calibration prior to its use. Steam cycle parameters are measured with calibrated instrumentation and then test results corrected to reflect the true readings.

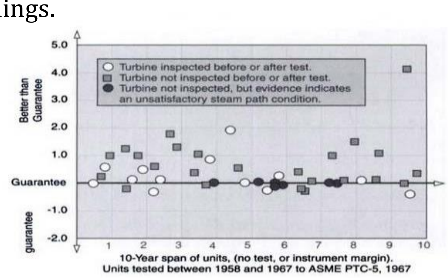

Fig 3.1: Performance Test Results of Steam Turbine

3.3 TYPES OF PERFORMANCE TEST

The following classification is provided for convenience. Calibration of servo-, motor Calibration of pressure gauge & pressure transmitter

4 MECHANICAL RUN TEST OF STEAM TURBINE 4

Operating the turbine from zero to maximum continuous speed (MCS) at 10% increments approximately. Increasing the speed of the turbine to 1% below the trip speed and keeping the turbine running at that speed for 15 minutes. Reducing the speed to MCS and running the turbine at the rated speed for four hours continuously after stabilization of bearing and lube oil temperatures.

4.1 BASIC REQUIREMENTS FOR RUNNING TEST

Usage of contract bearings and couplings for the test, Maintenance of oil pressures and temperatures during the test within the specified ranges recommended, Test stand oil filtration system is of 10 microns, Measurement of bearing lube oil flow rates during test at maximum continuous speed, Ensuring the casings and job oil systems free from leakages, Checking of all warnings, protective and control devices for proper functioning, Maintaining steam parameters as close to the specified normal values as practicable.

4.2 Satisfactory Mechanical behavior of the turbine is ensured during the test

Unfiltered shaft and bearing housing vibration readings are recorded throughout the operating speed range and at over speed. These values conform to the allowable limits of API 612 Clause 2, 8, 2, 4/ VDI 2056/ ISO 10816-2 RMS vibration velocity mm/sec in case of bearing housing vibrations and VDI 2059/ISO 7919-2 for shaft vibrations (peak –peak) relative displacement of shaft micrometers. In addition to test log sheets of vibration amplitudes are also plotted.

4.3 THE FOLLOWING TESTS ARE CONDUCTED ON TURBINE GOVERNING SYSTEM

Demonstration of the turbine trip by operating the hand trip lever, Testing of over speed governor with oil by means of over speed governor tester at maximum continuous speed, Checking of over speed governor and if necessary adjusting it to +1 or -1 % of nominal trip speed setting, Measurement of run down time of the turbine from over speed/MCS to zero RPM.

4.3 PRE-TESTING ACTIVITIES

Steam line blowing, Lube oil line flushing, Governing oil line flushing, Jacking oil line flushing, Turning oil line flushing, Installation of bearings.

4.4 MECHANICAL RUN TEST OF STEAM TURBINE (M.R.T)

The initial testing of a steam turbine at No-Load conditions is Mechanical Run Test, M.R.T is done only after all the pre testing activities are conducted, To start the turbine initially the main stem inlet valve is opened followed by the opening of the Emergency Stop Valve (E.S.V) to admit steam in to the steam chest of the turbine, Once the steam has been admitted into the steam chest the Woodward governor is reset and initial speed value is entered, this slowly opens servo-control inlet valve till the turbine reaches the set speed, The turbine is initially run at slow speed of 500 to 1000 rpm in order to heat the turbine evenly to allow even expansion of all the components. In case of hot this is not required.

4.5 M.R.TOFM/SBHELR&DTURBINEW.O.NO.101-001-00

Turbine capacity	–	8 MW.
Rated speed	–	11500 rpm.
Type	–	Impulse / T-0545.
Critical speed	–	3000 to 3800 rpm.

After the above mentioned procedure was carried then the turbine was taken to 10% of the rated speed, once the turbine reached this speed. All the other parameters of steam and the turbine are continuously monitored on through the Distributed Control System (D.C.S),Once the turbine was run at 10% speed with stability, the speed was increased by 10% each time and the readings were taken as before, Care was taken that the turbine is not run in the critical speed range in any case for longer durations, Once the turbine reached its rated speed it was run for a longer duration in order to test its stability at the rated speed, After this the over-speed test was conducted, In order to conduct the over-speed test, the turbine's speed is increased beyond its rated speed till it trips due to over-speeding, In any case the speed of the turbine shall not increase beyond 110% of the rated speed, For the present turbine the expected maximum over-speed before the turbine went into trip condition was set to 12300-12900 rpm.

4.6 PROBLEMS FACED IN THE TURBINE DURING M.R.T ON 21/12/2016

Turbine was getting tripped the moment steam was admitted. On verification it was found that the center cap (for adjusting the wt.) was loose and came out, no grubbing was there, existing one got damaged while repair. New one was made, Over speed was occurring at 11250 rpm (before turbine reaching rated speed) - pin length was 7mm (wt.) was 0.7 gr. Reduced pin wt. To 0.6 grams OST occurred at 11450rpm, As further cutting pin length was not possible, it was decided to add 0.3 mm washer under the spring and with full length pin (29mm), Again trial was made and found the M/c was tripping on steam admission, up on verification it was found that the over speed bolt projected out due to the new cap and increased pin length. Pin (wt.) length was reduced by 5 mm and assembled back/c rolled and found that the vibrations were reaching above 100 microns during critical speed, It was decided to set the over speed pin tripping and send the rotor for balancing, Over speed is set after several trials and pin length is 9mm, Turbine vibrations were 65- 70 microns at MCS at an exhaust hood temp. Of above 70deg, When Ex. hood temperature was brought down below 45 deg. vibrations came down to 15-20 microns

5 OBSERVATIONS 5

Since OST occurred before rated speed the turbine could not be taken to its rated speed, The over speed governor pin length was decreased in order to increase OST speed value, Inspire of decreasing the pin length there was no considerable change in OST occurrence, Hence the only other way was to increase the force required to trip and hence a washer was added under the spring. A 0.3mm washer was added along with a full length pinion the final day of testing an increase in magnitude of vibrations was observed, when I compared the log sheets from the previous day and that day I noted that there was also an increase in the exhaust hood temperature.

6 CONCLUSIONS 6

Testing is a very important aspect of production and is a must for reliable products and also improvement of products.

IMPULSE Turbine is a very sensitive turbine and requires a better control and monitoring facility for its proper running when compared to other Turbines every department has its own Quality Circle which always thrives to increase the productivity of their department and hence help in increasing the profits of the firm.

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