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Analysis of Variable Speed Turbo Coupling in Boiler Feed Pump

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Abstract: In Tuticorin Thermal Power Plant, the thermal energy is converted to mechanical energy and it's converted to electrical energy. The thermal power plant operates on modified rankine cycle with reheating and regeneration. This cycle is a closed cycle. In order to circulate the de-mineralized water in the rate of 700 tons per hour at 175Kg/Cm2. The de-mineralized water is circulated by boiler feed pump it is coupled with the constant speed motor. In this operation, 15 years back the throttle control was used to control the circulation of de-mineralized water to boiler drum. This throttle control method is inefficient method. To overcome this throttle control is replaced by speed control. The variable speed turbo coupling is used for speed control. The variable speed turbo coupling receives the power from constant speed motor and delivers the power at variable speed. By using this variable speed turbo coupling the quantity of de-mineralized water is pumped to the boiler drum can be varied. The transmission efficiency of variable speed turbo coupling is not constant throughout the variable speed range. The transmission efficiency is more at same percentage of speed. By analyzing the performance curve of the variable speed turbo coupling the most efficient power transmission scoop position is identified. Our project is based on, 1. Analysis the scoop position at which the power transmission is high by using the performance curve.2. Analysis the scoop position at which the boiler feed pump are operate on maximum period in any one unit (TTPS). 3. Analysis to the maximum duration operated scoop position by which avoiding energy losses due to operating at inefficient energy transmission efficiency position (scoop position).

Keywords: Boiler feed pump, Efficiency, Herring bone gear, Rankine cycle , Variable speed turbo coupling.

Introduction

Voith geared variable-speed couplings combine mechanical gears and a hydrodynamic variable speed turbo coupling in one common housing. The oil tank is bolted to the bottom of the housing. The gear stage is arranged on the input side of the coupling. Both working and lube oil are supplied from the integrated oil tank, but have separate circuits. The oil system can also be used to supply both the motor and the driven machine with lube oil

Rankine Cycle

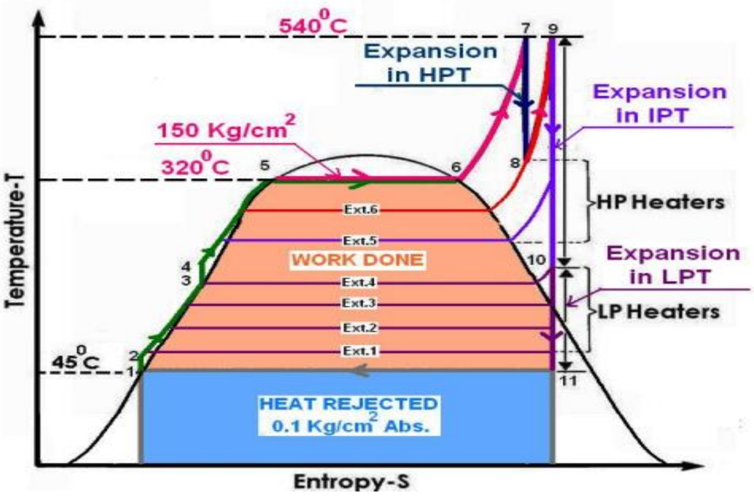

Fig1. Rankine Cycle

A thermal power plant basically works on Rankine cycle.
Process of rankine cycle:

1-2 Work input by CEP pump.

2-3 Isentropic heat addition process LPH1, LH2, LPH3.

3-4 Work input by boiler feed pump.

4-5 Isentropic heat addition process HPH4, HPH5, Economizer.

5-6 Latent heat addition process in furnaces.

6-7 Super heating process.

7-8 Isentropic heat expansion in HP TURBINE.

8-9 Reheating process (heat addition process).

9-10 Isentropic Heat expansion in IP TURBINE.

10-11 Isentropic Heat expansion in LP TURBINE.

Working Principle In Tuticorin Thermal Power Plant

Step 1: Initially the working fluid is being stored in the hot well .The working fluid is then pressurized using a condensate extraction pump. It is nothing but a simple centrifugal pump. This pump pressurizes the fluid to a pressure of about 8 kg / cm² and the temperature of the fluid is 50° C.

Step 2: Low Pressure Heaters and Gland Steam Cooler: In this process the pressurized fluid at a pressure of 8 kg / cm² and at 50° C is availed to the Low Pressure Heaters from the hot well using the Condensate Contraction Pump. This heating process is done by taking a part of the steam from the IP turbine. There are total of three Low Pressure Heaters kept in series and then a Gland Steam Cooler. All these heaters help in the process of isentropic heating of the working fluid to a temperature of about 120° C and pressure remains the same, i.e., 8 kg / cm².

Step 3: De-aerator: The working fluid, though is De-mineralized, may contain some dissolved oxygen trapped in the intermolecular spaces which have to be removed in order to avoid the corrosion process. This process can be done in many ways. i.e., it's given above.

The up flow of the steam carries the dissolved oxygen with them and de-aerates the working fluid. During this process a part of the steam condense and get collected along with the feed water tank. A part of it with the oxygen passes to the vent condenser when the steam is cooled and the gaseous oxygen is liberated. Again the water from the vent condenser passes through the de-aerator and finally collected in the feed storage tank.

Step 4: Boiler Feed Pump: The working fluid after the de-aeration process is then fed into the boiler for further heating process. This is the region where the highest pressure of the working fluid is achieved. i.e., around 175 kg / cm².Boiler feed pump is nothing but a large scale centrifugal pump with very high discharge and pump the water to the boiler drum which is at a height of around 53 meter.

Step 5: Economizer and Boiler: Feed water is fed to the boiler drum through the economizer. Water then enters in bottom ring header through six numbers of down comers. In boiler furnace, coal is fired with fuel oil. The heat energy developed by combustion of coal in furnace is utilized for the evaporation of water in water walls. As the density of steam is lower than water, this water steam mixture enters in boiler drum without help of any pump. This is called natural circulation. In boiler drum, steam is separated from the mixture in three steps i.e. cyclone separators (Primary separators), secondary separators and screen dryers (Final separators). Steam that comes out of boiler is called saturated steam. This saturated steam is then passed through number of super heaters i.e. primary, platen and final for superheating of steam to a temperature of 540°c. (Pressure being 138 Kg/cm²).

Boiler is sealed from the bottom by seal water arrangement to prevent any ingress of atmospheric air into the boiler. Bottom of the boiler is shaped like a hopper. Bottom ash falls in the bottom hopper and after crushing it is transferred to ash handling plant .Fly ash along with the flue gases goes through ESP where fine ash is taken out and sends to the ash handling plant for further processing to the ash bunds.

Step 6: Superheating of the Steam (HSH, PSH, and FSH): After heating the water (latent heating) and converting it into the steam, the temperature raises to about 420° C. Then it has to be super heated before it is passed through the turbines. For this process we have three super heaters in sequence to attain a final super heated temperature of about 540° C. The super heaters used are Horizontal Super Heater, Platen Super Heater and Final Super Heater. All these super heaters use the flue gases and use their heat to super heat the steam.

Step 7: Conversion of Heat Energy into Mechanical Energy (HPT):The outlet from the super heater let out the working fluid at a temperature of about 540° C and 140 kg / cm pressure which is then passed into the High Pressure turbine. High Pressure Turbine consists of 20 stage blades which harden the heat energy and use them and convert into mechanical energy. The rating of the HPT is 10000 rpm but spins at around 3000 rpm. A single shaft is connected all through, starting from HPT, IPT, LPT and Generator. The working fluid is isentropic ally expanded.

Step 8: Reheating of the Expanded Working Fluid: The outlet of the working fluid from the HPT Is called Cold Reheat, which is then again reheated. The outlet from the HPT is then taken to the Re heater inlet. The fluid coming out will be at a temperature of about 278.5° C and at 37.1 kg / cm².This condition of the fluid is then elevated to a temperature of 525° C and at the same pressure again using the Reheater which uses the flue gases. This process is nothing but isentropic heat addition.

Step 9: Isentropic Expansion of Reheated Fluid: (Intermediate Pressure Turbine) The working fluid is then passed through the IPT.IPT consists of 2 stages which again efficiently convert the pressure energy of the working fluid to mechanical energy then to electrical energy. Isentropic expansion of the working fluid takes place here.

Step 10: Further isentropic expansion in LPT: The outlet from IPT is then directly given to the inlet of the LPT.LPT has 7stages and is comparatively in large size than other two turbines. This further isentropic ally expands the working fluid by using will be its pressure energy and converting it into mechanical energy and subsequently into electrical energy.

Step 11: Electrical Energy Conversion: The generator used converts all the mechanical energy at all stage i.e., HPT, IPT and LPT and coverts them into electrical energy. The turbine is directly coupled to the generator rotor. Electricity is generated as per the “Faradays Law” in generator. Boiler produces super heated steam of pressure 138 Kg/cm² & 540°c temp. This steam enters in steam turbine and due to the heat energy of steam; turbine rotates at about 3000 rpm. In alternator time varying magnetic field is produced by rotating field winding with help of turbine

The rating of the generator being used here is as follows

Voltage produced : 15.7 KV

Shaft speed (rotor) : 3000 rpm

Frequency : 50

Variable Speed Turbo Coupling

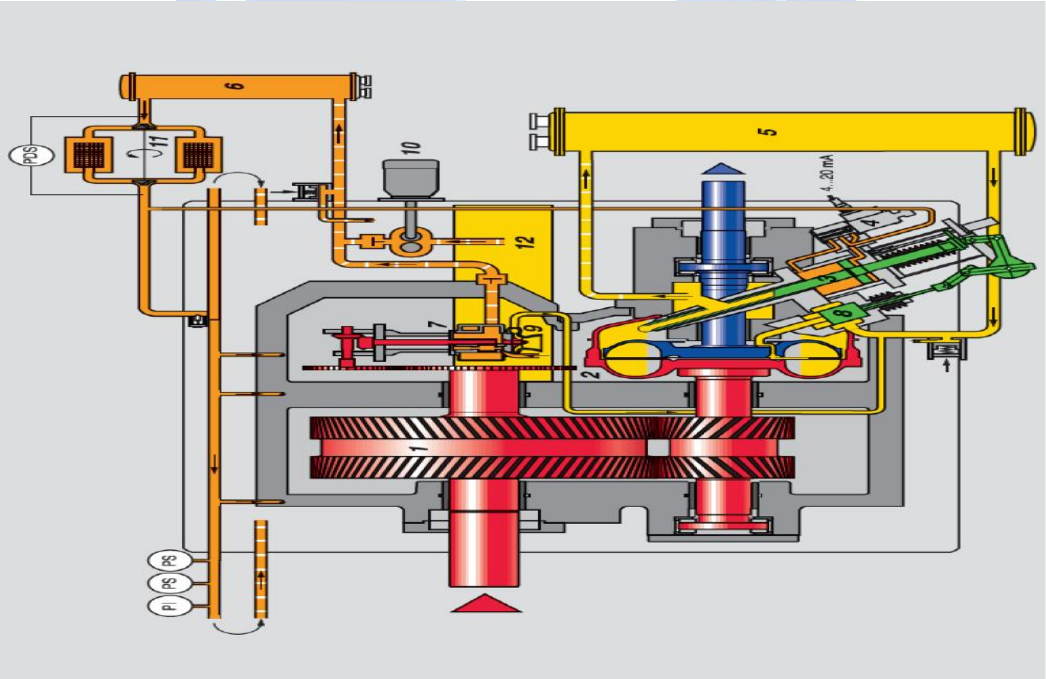

Fig2. Variable Speed Turbo Coupling

Main parts:

A. Primary wheel and Secondary wheel.

B. Shell.

C. Scoop tube position.

D. Herring bone gear.

E. Working Oil.

Constructional Features

A. Primary wheel and Secondary wheel:

Primary wheel is the impeller which is the output of the squirrel motor (constant speed) is given as input to the shell.

Secondary wheel is the turbine which is connected to the working machine (boiler feed pump).Both have a large number of straight radial vanes.

B. Shell:

Shell is the oil chamber where the primary wheel and secondary wheel are incorporated mutual housing. The chamber contains the working oil between the impeller and turbine. Working oil used to transmit hydrodynamic force from impeller to turbine.

C. Scoop tube:

The guide bolt is moved by turning the adjusting lever and thus the cam disc. To ensure permanent contact with the cam disc the guide bolt is loaded by the pressure spring. The motion of guide piece is transmitted by the pinion to the control shaft.

The control shaft has a gear segment which meshes with the gear teeth on the scoop tube. The scoop tube is located by the guide bush and secured by the guide bolt against torsion. The actuator must be provided with stops which limit the scoop tube in the end positions “MIN” and “MAX”. the limitation must not be in the control block or on the scoop tube.

D. Herring bone gear:

Herringbone gears, also called double helical gears, are gear sets designed to transmit power through parallel or, less commonly, perpendicular axes. The unique tooth structure of a herringbone gear consists of two adjoining, opposite helixes that appear in the shape of the letter 'V'.

Herringbone gears mate via the use of smooth, precisely manufactured V-shaped teeth. Like helical gears multiple teeth are engaged during rotation, distributing the work load and offering quiet operation.

However, due to their tooth structure, herringbone gears nullify the axial thrust typical of helical gears.

The gear set's teeth may be manufactured so that tooth-tip aligns with the opposite tooth-tip, or so tooth-tip aligns with the opposite gear's tooth trough.

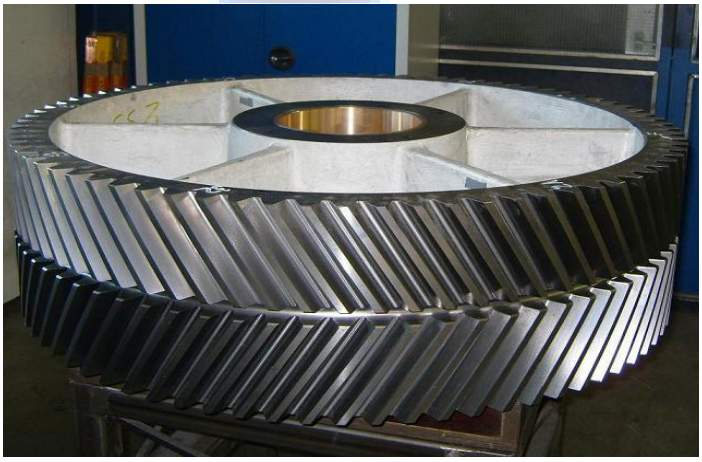

Fig3. Hearing bone gear

E. Working Oil:

A continuous monitoring of geared variable speed turbo coupling maintaining admissible temperature lube pressure and oil level means a trouble free operation and low maintenance. The viscosity of operating oil for startup must not exceed 250 mm /s². For the oil, according to our oil selection list 3.625-6073e.This means an oil temperature of at least + 5° C.

The geared variable speed turbo coupling can start and stop with the scoop tube at minimum position. The main motor can run up under virtually no level.To keep good air separated the sump temperature must not fall below 45° C.

For tail spin coupling slowly turning with the unit and stands till the auxiliary lube pump must be switched on to lubricate the bearing.Reverse rotation of coupling output shaft is permissible under the following condition (1 to 3 min).Reverse rotation of coupling secondary shaft is allowed up to 1/3 of the maximum speed with Switched-on auxiliary lube pump.

Table 1: Performance Characteristic Calculation of boiler feed pump in TTPS

S.No	**Output Speed**	**Scoop position**	**Flow rate**	**Power input**	**Total head**	**Power output**	**Power loss**	**η**
Unit	**Rpm**	**%**	**T/hr**	**Kw**	**m**	**Kw**	**Kw**	**%**
1	3180	35	154	1596.6	1070.87	449.03	1147.57	28.1
2	3376	40	205	1729.5	1126.07	662.14	1067.45	38.2
3	3744	55	227	2136.5	1291.67	798.92	1337.63	37.3
4	3947	65	350	2441.1	1302.7	1241.8	1199.35	50.8
5	4178	70	370	2645.2	1368.95	1380.9	1264.34	52.0
6	4498	80	388	2848.7	1796.2	1899.2	949.52	66.6
7	5140	100	395	2532.9	2149	2051.6	498.9	81

Table 2: Data Sheet For Variable Speed Turbo Coupling In Boiler Feed Pump

S.No	**Load current**	**Flow rate**	**Pressure**	**Scoop position**	**Speed**
Unit	**Amps**	**T/hr**	**Kg/cm**	**%**	**Rpm**
1	155	154	97	35	3180
2	170	205	102	40	3376
3	210	227	117	55	3745
4	240	350	118	65	3947
5	260	390	124	70	4178

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Calculation of Hydraulic Power Output For TTPS In

Unit 5-A:

Hydraulic power output =Flow rate * total head * gravity force * density / 1000

Flow rate Q = 388 T / hr

= 348 * 1000 /3600

= 107.966 m³/sec

Efficiency of the TTPS unit 5-A (24/2/2012)

Efficiency =output power/input power

=1472.82 / 2848.73

Efficiency of boiler feed pump existing condition =66.66%

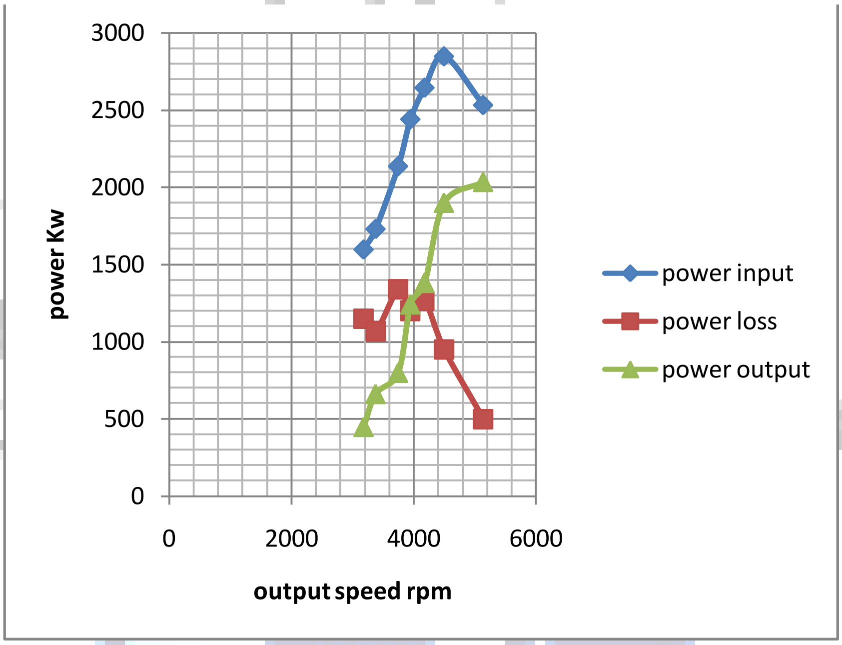

Fig4. Performance graph

a) Analyzing existing condition

In the existing condition the input speed of the turbo coupling is 5285 rpm with the gear ratio 3.56 and constant speed motor at 1485 rpm At the full load condition the slip loss is 2%. Therefore the output speed is 5180 rpm. The performance characteristics of variable speed turbo coupling in existing condition is given below

b) Maximize / minimize the value

In variable speed turbo coupling R16 K.1 is constructed with the gear ratio of 3.56. Optimization of variable speed turbo coupling is done by varying the gear ratio. Following are the performance curve of various gear ratios.

c) Consolidating value:

1) Comparing the above gear ratio performance curve of variable speed turbo coupling
2) Were gear ratio 3.51,3.2,3.53 are omitted because they not meet the ouput range speed 5140 rpm.
3) The other gear ratio 3.54,3.55,3.56,3.57,3.58 are consolidated in the below graph
4) Finally analyze the power loss.

Table3. Result of Optimization

S.no	Before Optimization	After Optimization
Unit load	210 Mw	210 Mw
Power output	4000 Kw	3972.65Kw
Power loss	700 Kw	672.89 Kw
Output speed	4498 rpm	4448 rpm

Conclusion

The herring bone gear is the major power transmission part of the variable speed turbo coupling, which will increase the input speed of the coupling. In our project, By varying the gear ratio various output power and power loss corresponding to the particular various scoop position and from the output power and power loss graphs we have concluded 3.54 gear ratio is the most efficient among the range of 3.51 to 3.58. In this point, we can get the power saving of 27.65 Kw and cost about Rs 6,55,535 lakhs/year. It is need not required to replace the gears immediately, as these spares have served more than 20 years it can be scheduled in next renewal. After replacing the gear ratio, the efficiency of coupling will be increased from 85.14% to 87.5% and output speed is reduced as 4448 rpm.

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