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Steam Power Plant Performance Operating at High Temperature and Pressure Conditions

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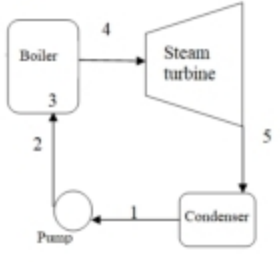
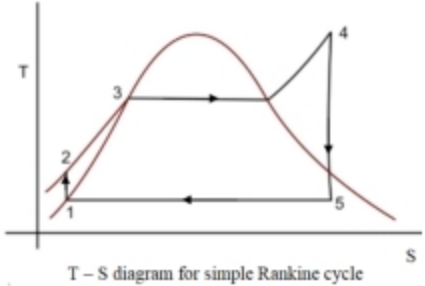
Introduction

A steam power plant plays a big role in producing electric power through out the world. Therefore improving its performance would lead to increase the power output, thermal efficiency, work ratio and in addition to that reducing the cost of the unit power.

In early days of producing electric power by steam power plants, they were operating on a simple Rankine cycle mode and surely they had low thermal



Simple Rankine cycle



T – S diagram for simple Rankine cycle

Mathematical Models

simple steam power plant (based on Rankin cycle) consist of a boiler to generate a superheated steam , a steam turbine to produce work due to thermal expansion of steam , a condenser to convert steam to saturated water and a feed pump to raise the condensate water boiler pressure. However, in a cogeneration steam power plant, feed water heaters either open or closed feed water heaters are used to improve the performance of the cycle.

Boiler:

Regenerative – reheat cycle with intermediate steam extraction:

$$q_{total} = q_{1-11} + q_{3-4} = (h_1 - h_{11}) + (1 - y_1 - y_2) * (h_4 - h_3)$$

Steam turbine:

Regenerative – reheat Rankin cycle with intermediate steam extraction: the amount of work output per unit mass

$$w_{st} = w_{s.t1} + w_{s.t2} = [(h_1 - h_2) + (y_1) * (h_2 - h_3)] + (1 - y1 - y2) * (h_5 - h_6) \quad (kJ/kg)$$

Mathematical Models

Condenser:

Regenerative – reheat Rankin cycle with intermediate steam extraction: the amount of heat rejected per unit mass

$q_{6-7} = (1\text{-}y1\text{-}\ y2)*(h_6 - h_7)$ (kJ/kg)

Feed water pump:

Regenerative – reheat Rankin cycle with intermediate steam extraction: the amount of work input per unit mass is given as follows:

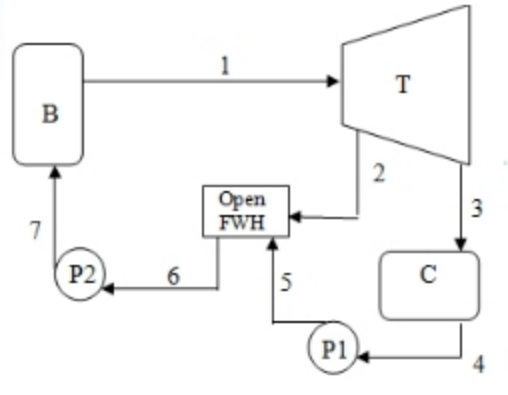
$w_p = w_{p1} + w_{p2} = (1\text{-}y1\text{-}\ y2)\ (h_8 - h_7) + y2\ (h_7 - h_6)$ (kJ/kg)

The performance of steam power plant either the simple cycle or modified cycle will be obtained with aid of EES (Engineering Equation Solver) which provide the user by all properties of steam at all states.

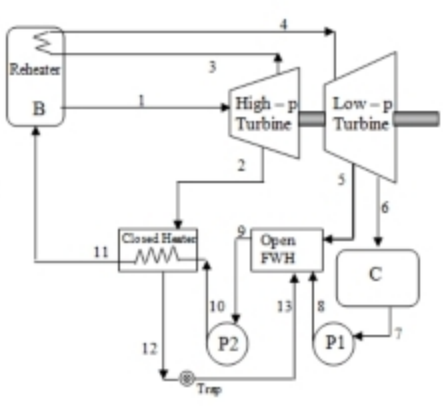
$y_1 = (h_{11} - h_{10}) / (h_2 - h_{12})$

$y_2 = \{(1 - y_1)*h_8 + y_1 * h_{13} - h_9\} / (h_8 - h_5)$

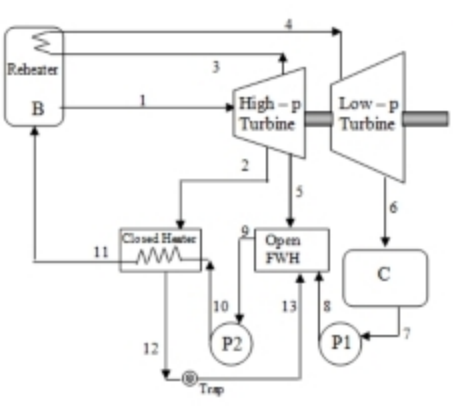
Mathematical Models



The ideal Regenerative Rankine cycle with an open feedwater heater

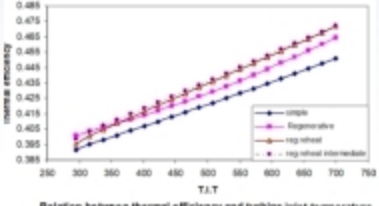


The ideal Regenerative Rankine cycle with closed and open feedwater heater

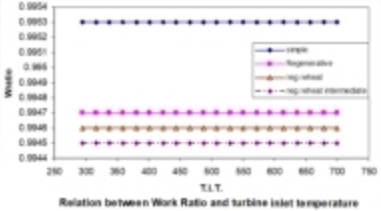


The ideal Regenerative Rankine cycle with closed and open feedwater heater (intermediate case)

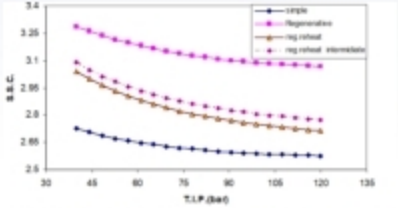
Results



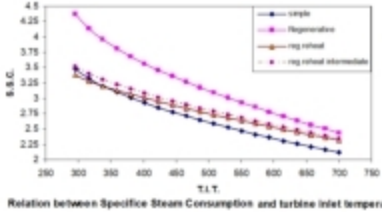
Relation between thermal efficiency and turbine inlet temperature



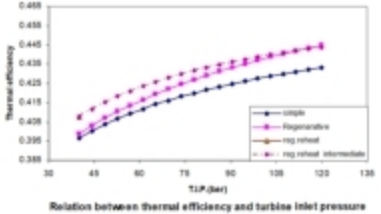
Relation between Work Ratio and turbine inlet temperature



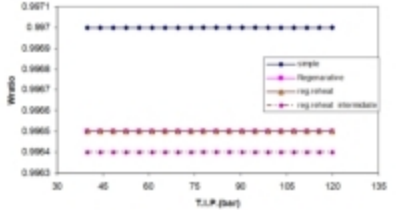
Relation between Specifice Steam Consumption and turbine inlet pressure



Relation between Specifice Steam Consumption and turbine inlet temperature



Relation between thermal efficiency and turbine inlet pressure



Relation between Work Ratio and turbine inlet pressure

Conclusions

1- Regenerative – reheat cycle with intermediate steam extraction give a high thermal efficiency (47.23%) at case 1 and (44.36%) at case 2 as compared to simple and regenerative steam power plants. Obviously thermal efficiency increase nearly by (4.77 %) relatively to other, low specific steam consumption in comparison with other.

2- Results also show that simple cycle plant has low thermal efficiency, high specific steam consumption.

3- The work ratio decrease as the turbine inlet temperature increase and show the minimum value for regenerative cycle.

4- The effect of turbine inlet temperature and turbine pressure was obvious and shows a positive effect throughout all considered cases.