INVESTIGATION OF THE PERFORMANCE OF BACK-PRESSURE STEAM TURBINES COMBINED WITH THERMO-COMPRESSORS

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Degree of Master of Engineering

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DECLARATION OF THE CANDIDATE AND SUPERVISOR

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Abstract

Steam is highly used in most of the industries. There are many occasions where low pressure steam is used. Most of the times, relatively higher pressure is generated, transported and finally the pressure is reduced before use. Throttling devices are used for reducing pressure. Throttling valves or pressure reducing valves have been used for this work in most of the instances. There is a huge potential of utilizing this energy by introducing back pressure steam turbines. If the turbine exhaust pressure can be further dropped, power generation through the steam turbine can be increased. This research project was created to cover these areas.

There is no literature which can be used to calculate the power output of a turbine with known flow rates and input and output conditions. This project is aimed to give the information how much power is generated under the given conditions. This can be used for selecting a suitable back pressure turbine for the particular requirement. Giving the capital investment for such project also was an objective. It can be decided whether the selected project on retrofitting pressure reducing valves with the steam turbines is viable. There is no sufficient information on performance of thermo-compressors which can be used for increasing steam pressure. There is an objective of finding out the motive flow required for the known suction flow at known input and output conditions. As the title of the research shows, ultimate objective of this study was to see whether combining thermo-compressors to reduce back pressures is feasible or not.

This research project was done for five input steam conditions and six output steam conditions of the turbines. For a selected turbine, performance at known pressures was calculated. This information was graphically represented to give a clear picture. Similarly performance of thermo-compressors was calculated for known input and conditions. This information also was graphically represented. Finally the performance of the back pressure turbines were calculated when the back pressure dropped further by introducing thermo-compressors. Calculated values were graphically represented to check whether this was a viable option.

As per the outcome of this project, guide lines were made for back pressure steam turbines with different input and output conditions. As the input, superheated steam varying from 10barg at 350 deg. C up to 50 barg at 450 deg.C have been considered. Turbine exhaust pressures varying from 1 bara to 6 bara also have been considered. Guide lines were extended to show the cost of investment to retrofit pressure reducing valves with back pressure turbines. Guide lines were made on the amount of motive pressure consumed to increase the pressure of steam at different input and output conditions. These guidelines also were extended to show the capital investment of the installing thermo-compressors. Process steam pressures varying from 2 bara to 6 bara have been discussed against turbine exhaust pressures varying from 1 bara to 6 bara under the study of the behavior of the back pressure steam turbines combined with thermo-compressors. Further study was done to ensure whether there is any effect of the isentropic efficiency and the generator efficiency on this behavior. Finally, it was proved that there was no benefit of operating the back pressure steam turbines at lower exhaust pressure by introducing thermo-compressors and increasing the pressure before giving to the process for the pressure and temperature ranges covered in this study.

Retrofitting of PRV with steam turbines seems to be an attractive option. This study discussed only the application of superheated steam. Further studies can be extended to saturated steam to use single stage steam turbines. Introducing of thermo-compressors for specific industries also can be done as a further study. However, further study of introducing thermo-compressors to enhance performance of back pressure turbine will not be done as it seems not viable.

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W. P. J. K. Wickramasinghe

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ABBREVIATION

A_2/A_1	Area Ratio
E_B	Energy consumption of the boiler
h_2	Enthalpy of outlet steam
h_2'	Enthalpy for isentropic expansion
η_B	Efficiency of the boiler
h_B	Enthalpy of steam
η_{gen}	Efficiency of the generator
h_i	Enthalpy of inlet steam
η_{issen}	Isentropic efficiency of the turbine
h_iw	Enthalpy of feed water
h_o3	Enthalpy of discharge steam
h_oa	Enthalpy of motive steam
h_ob	Enthalpy of suction steam
h_p	Enthalpy of process steam
LCV	LCV of fuel
m_B	Fuel consumption of the boiler
P_i	Turbine inlet pressure
P_o	Turbine outlet pressure
P_o3	Discharge Pressure
P_o3/P_oa	Compression Ratio
P_oa	Motive Pressure
P_ob	Suction Pressure
P_ob/P_oa	Suction to Motive Ratio
P_p	Pressure of process steam
P_T	Power output
PRV	Pressure Reducing Valve
S_i	Entropy of inlet steam
T_i	Temperature of inlet steam
T_o3	Discharge Temperature
T_o3	Discharge Temperature

T_oa	Motive Temperature
T_ob	Suction Temperature
W/W_a	Corrected Entrainment Ratio
W_a	Motive Stream
W_b	Suction Stream
W_B	Steam generation of the boiler
W_b/W_a	Entrainment Ratio
W_i	Steam flow rate through the turbine
W_o3	Discharge Stream
W_p	Mass flow rate of process steam
X	Condition of process steam