Calculation method of back pressure correction coefficient of steam turbine

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Abstract. With a 660MW ultra-supercritical steam turbine unit as the research object, the back pressure correction curves of the unit THA condition and 75%THA condition were obtained by the micro increase output test. During the test, the flow of condensate was kept unchanged to avoid the influence of the changes of the low-pressure regenerative extraction flow on the test results.

1. Introduction

In order to understand the impact of the steam turbine back pressure on the output and economy of the unit, it's the most direct way to check the back pressure correction curves provided by the manufacturer[1]. But most manufacturers only provide back pressure correction curves under some typical conditions and even only provide back pressure correction curves under rated condition, it is more difficult to meet the needs of field applications[2]. This paper presents a simpler conventional heat balance calculation for the power backpressure.

2. Case introduction

Taking 660 MW ultra-supercritical unit as the research object, the back pressure correction curves of the unit THA condition and 75%THA condition were obtained by the conventional heat balance calculation, and were compared with the manufacturer's correction curve.

2.1. Unit overview

The steam turbine is N660-25/600/600 ultra-supercritical, one intermediate reheat, single axis, combined HP-IP cylinder, three cylinders, four exhaust ports, double back pressure condensing steam turbine.

Table 1. Design data of the unit

Project name	THA	75%THA
Unit load(MW)	660	495
Main steam pressure(MPa)	25.00	20.70
Main steam temperature(℃)	600.0	600.0
Reheat steam pressure(MPa)	4.42	3.30
Reheat steam temperature(℃)	600.0	600.0
Seventh extraction steam pressure(MPa)	0.111	0.084
Seventh extraction steam temperature(℃)	122.2	124.4
Eighth extraction steam pressure(MPa)	0.049	0.038

Eighth extraction steam temperature (°C)	81.0	74.8
Exhaust flow(t.h^{-1})	1035	805
Back pressure(kPa)	5.54	5.54
Condensate pump water temperature(°C)	35.0	35.0
Feed pump turbine inlet flow(t.h^{-1})	92.8	53.6
Feed pump turbine exhaust pressure(kPa)	6.34	5.84

2.2. Exhaust loss curve
The thermal tool provided by the turbine manufacturer contains information on the loss of low-pressure exhaust steam, traditionally known as "exhaust loss curve"[3]. This curve shows the loss of exhaust enthalpy at the average exhaust steam velocity determined by the back pressure and / or exhaust flow of the steam turbine. In general, the last stage blade exhaust loss includes four items: the residual velocity loss, the losing-flow loss, the flow loss of exhaust cylinder and the blocking loss, the residual speed loss is the main item[4]. For some turbine manufacturers, the use of this curve also requires a correction of humidity because the average steam exhaust velocity is a function of the volume flow for a given exhaust geometry, and its value depends on the backpressure and steam mass flow. FIG. 1 shows the last stage blade exhaust loss curve provided by the manufacturer.

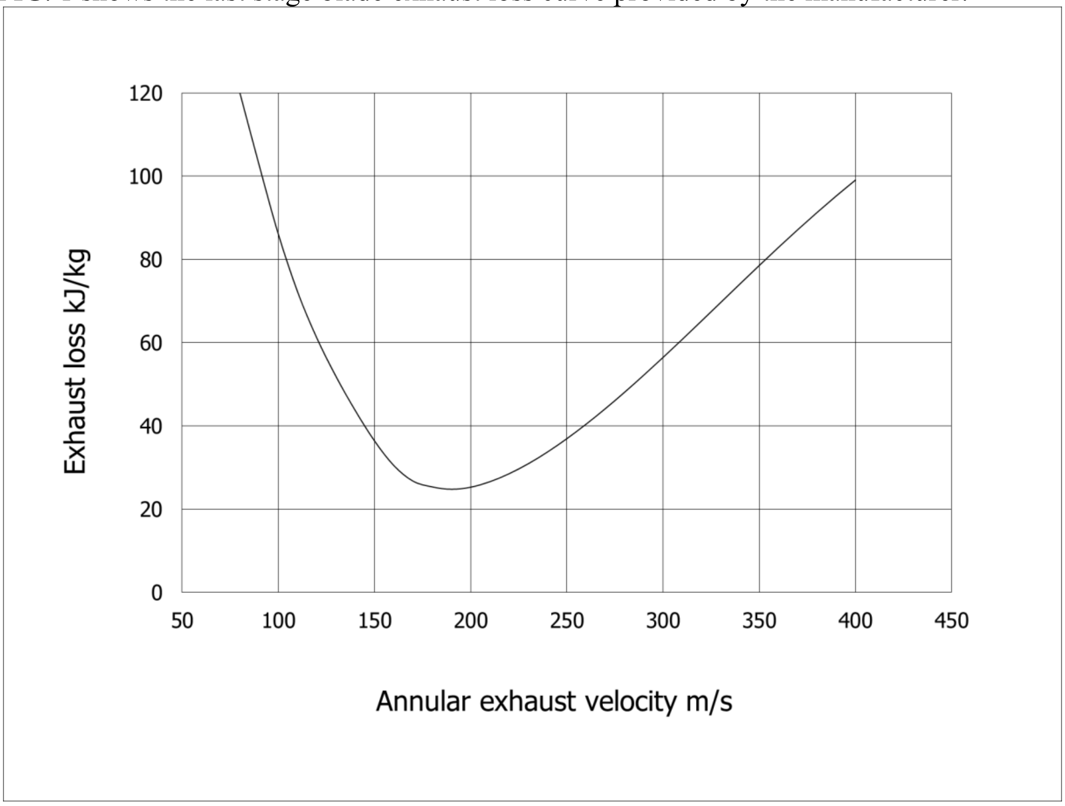

Fig.1 The exhaust loss curve of the last stage blade

3. Calculation basis and result analysis of the conventional heat balance alculation
The conventional heat balance calculation method is is currently more accurate method of calculating the thermal system variable conditions, which is usually used as the basis for comparison of other calculation methods. When the back pressure changes, the change of the electrical power of the steam turbine generator is calculated through the thermal balance of the steam turbine thermal system.

Although the enthalpy drop of the last stage is much larger than that of the other intermediate stages, it’s proportion of the total insulation enthalpy drop in the turbine is still quite small. For the condensing turbine with feed water regenerative system, the flow of the last stage is smaller than that of most other stages, so the power generated by the last stage is only 1/10 ~ 1/15 of the total turbine power. As a result, taking the steam flow at the average radius section as a representative to carry out the last stage variable condition calculation, even if there are some errors, the influence on the calculation accuracy of the whole turbine variable condition calculation is also small. The essence of the simplified calculation method is that the last stage should also be classified as an intermediate stage group in principle, which does not require a detailed variable condition calculation of the stage group and only need a variable condition calculation of the individual loss items in the last stage (mainly for the residual velocity loss and and the moisture loss) [5].

When the backpressure changes, considering the last stage as one of the intermediate stages (ie, assuming the steam turbine expansion process line is constant), its residual velocity loss becomes an external loss to the steam turbine which can be obtained by checking the manufacturer's exhaust loss curve[5]. It should be noted that, in this paper, the influence of moisture loss on unit power is not considered.

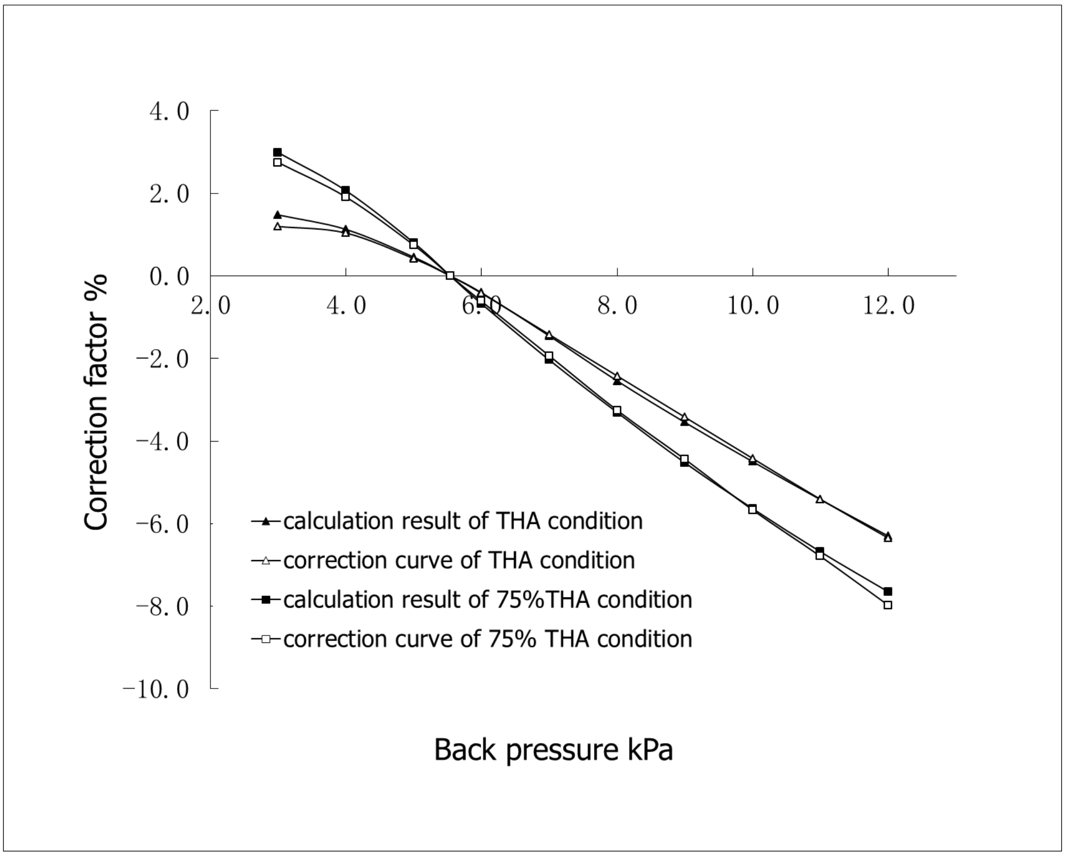

Fig.2 The back pressure correction curve

FIG. 2 shows the results of conventional thermal balance calculations of THA and 75%THA, which is drawn together with the back pressure correction curve provided by the manufacturer. Under the condition of THA and 75% THA, the conventional heat balance calculation method shows that the back pressure correction curve basically coincides with the curve provided by the manufacturer; when the back pressure is greater than or equal to 5.54 kPa, the manufacturer's correction curve is linear as a whole, while there is a certain arc in the conventional heat balance calculation curve.

In summary, the steam turbine back pressure correction curve obtained by the conventional heat balance calculation method has high accuracy and good consistency with the manufacturer's correction curve.

4. Conclusion

Because the conventional heat balance calculation method takes into account various factors such as the enthalpy drop of the low pressure cylinder, the last stage exhaust loss, the change of the low extraction steam flow, etc. the steam turbine back pressure correction curve obtained by this method has high accuracy and good consistency with the manufacturer's correction curve. When the manufacturer only provides the back pressure correction curve of THA condition, the conventional heat balance calculation method is an effective way to obtain the back pressure correction curve in other conditions.

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