Furnace Convection Section Model facilitates 20% rise in Plant Capacity

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Abstract

Decoking of pyrolysis furnaces at a major ethylene complex posed a constraint in ethylene production. The slowdown affected the supply & sales schedule significantly. Root cause analysis of the symptoms exposed possible underutilization of furnaces. Analysis of furnace maintenance/operation history, onsite load tests, micromanagement and a robust model of the convection section of the furnace helped realize 20% increment in the throughput for the ethylene complex.

Introduction

At one of our client's overseas units the pyrolysis furnaces in an ethylene plant were being under utilized with regard to the design capacity. In addition to the routine loss in production worth millions of dollars, when any zone/furnace was taken off-line for decoking or for maintenance, the plant throughput reduced further specifically due to the constraint on furnace capacity. This affected ethylene production and consequently the bottom line, profit. Ingenero carried out an on-site audit of the cracking furnaces in the ethylene plant with a view to identify the reasons for not being able to achieve design throughput in the furnaces and suggest corrective actions to overcome the deficiencies.

Background - Ethylene Complex

Cracking furnace is the heart of a ethylene complex. Naphtha is cracked in steam cracking furnaces to get ethylene and propylene as main products. Cracking of naphtha produces a range of hydrocarbons from hydrogen to light cycle oil. The cracked gas is compressed and then different products are separated in a train of distillation columns. The lighter hydrocarbons are separated and used as fuel gas in furnaces and other hydrocarbons are separated in pure form which can be sold separately or as mixtures.

The complex in reference has eight Naphtha Pyrolysis Furnaces to produce ~450 KTA of olefins. Ethylene and propylene production is mainly dependent on the furnace process conditions like cracking temperature, coil pressure ratio, steam to oil ratio etc. These required process conditions decide the furnace operation. Higher cracking temperatures require harder furnace firing, higher fuel consumption.

In the induced draft furnace, the burner air registers and damper opening were adjusted to maintain the required excess air for the required fuel gas firing to ensure complete combustion.

The configuration of furnaces is such that two radiant zones have one common convection section for heat recovery. Heat from the burning in the furnace is recovered to preheat feed, BFW preheat, dilution steam superheating and high pressure steam superheating. The furnace thermal and fuel efficiency depends significantly on the heat recovery.

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Solution Design Methodology

It was a challenge to increase the throughput of furnaces at least to its design. There are many parameters which have a direct or indirect impact on the furnace capacity like coke formation, furnace runlength, tube elongation, carbonization, sudden thermal shocks due to unforeseen shutdowns etc. Based on this philosophy, following methodology was followed to arrive at a way to check feasibility and implement the capacity enhancement:

1. Review of historical plant operation, which includes historical runlength and yield data, operating procedures etc.
2. Review of furnace maintenance history, which includes failure reasons and maintenance practices
3. Robust model of the pyrolysis furnace including the convection section for the furnaces was developed. The model was developed to incorporate accurate behavior of the furnace along with equipment idiosyncrasies
4. This model was validated and tuned with the data acquired & reconsolidated from design books & actual operations. The model allowed calculation of furnace parameters that are usually not measured or are inaccurately available from field indications e.g skin temperature, heat flux distribution, accurate efficiency, etc.
5. Findings of the model/study were tested in the field through a test run on select furnaces. Based on the history and model predictions, ideal furnaces for test run were identified
6. Field inspection and monitoring of furnace fire box was carried out during the test run along with the recording of all possible process & equipment data.
7. Upon successful implementation of findings during the test run, Ingenero recommendations were implemented for all furnaces in the complex, consequently resulting in a significant capacity enhancement.

Maintenance history of all furnaces in convection and radiant section coils was reviewed and it was found that none of the furnaces had undergone a mechanical failure in the recent past. The plant operating data was analyzed in view of runlength and operating capacity. Two furnaces were identified for the test run based on their minimal failure history, lower runlength and lowest throughput (biggest possible step change).

A furnace model was built in FRNC5 for the selected furnaces based on the furnace data sheets, refer Figure 1. The model was validated for the plant operating data for different plant data cases. Fine tuning of the model was done based on bridge wall temperature, flue gas profile across convection section, process temperature & pressure drop of each convection section bank, varying internal & external fouling with furnace run-length and flue gas oxygen content which plays a vital role in the heat balance.

Critical parameters of convection section like furnace thermal efficiency, heat absorption in convection section banks and convection section tube metal temperatures

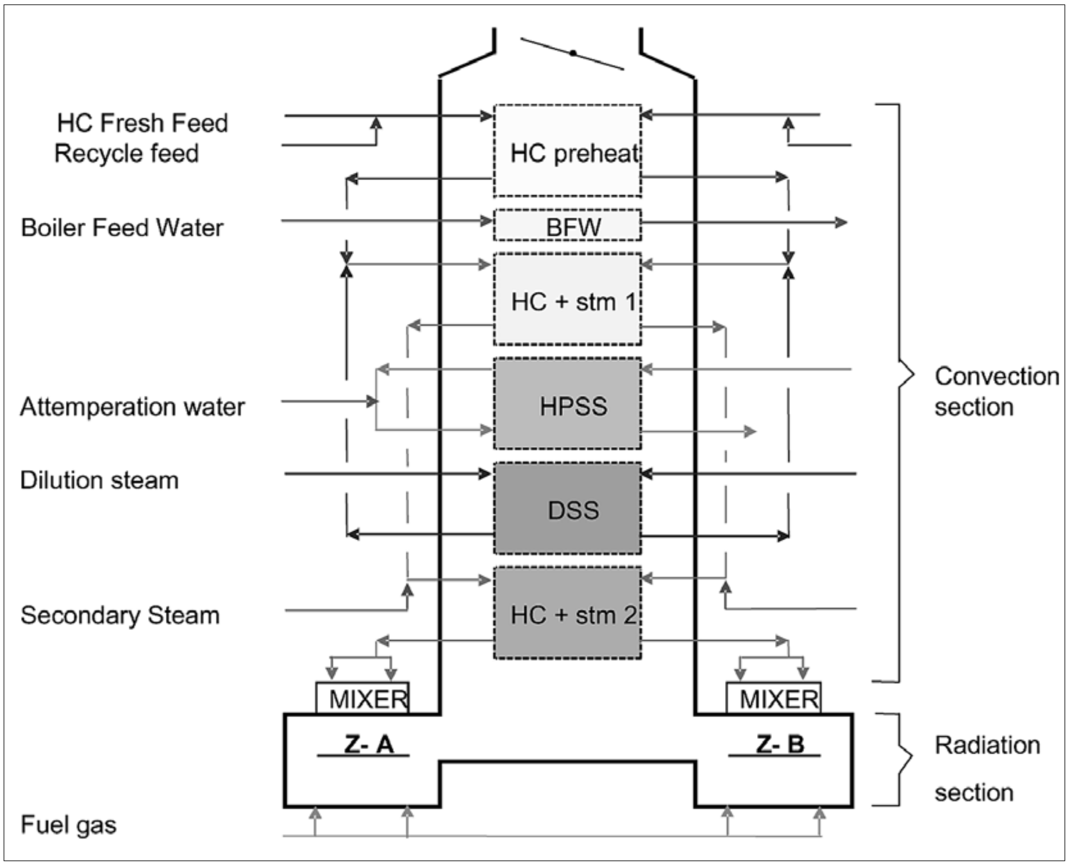

Figure 1: The convection section banks model in FRNC5

(TMT) were monitored closely for different plant data cases at varying plant furnace loads. The model was robust enough to indicate the minor deviations in the plant operating parameters.

While monitoring furnace operation using the model, field inspection and monitoring of furnace fire box for flame impingement, local hot spots in radiant box, TMT of radiant section tubes and excess air was also carried out simultaneously.

During the test run, the furnace load in Zone-A and Zone-B was 12 tph and 12.5 tph respectively, which was 84.5% of the design load (14.5 tph each zone). Field inspection at this load was conducted to observe any abnormality. It was observed that the tube metal temperatures of both the radiant zone coils were 1050°C and 1010°C at runlength of 17 and 7 days respectively. Other parameters like coil pressure ratio, excess air were maintained properly. Prior to start of the test run, FRNC model runs were undertaken for the present conditions to evaluate the furnace performance & additional capabilities. The estimated tube metal temperatures of all the tubes in convection section were well within the design limits specified in the data sheet.

Test Run

The furnace feed was increased in small steps of 0.5 tph per furnace. Plant parameters were maintained for 2-3 hours for every step increase. For each step increase in the furnace feed, field inspection was carried out to check any deviations in the operating parameters. Plant data was taken and model runs were carried out to monitor critical parameters like furnace efficiency and TMT of each row of convection section bank. It was observed that all the parameters were maintained within the normal operating range and/or below the design limits. While increasing the furnace throughput, other process parameters in furnace e.g. steam to oil ratio, coil outlet temperatures, excess air etc were maintained to get the desired cracking and product composition. Excess air was increased by opening burner air registers and stack damper opening.

The test run results & their analysis indicated that the furnace throughput was limited first due to high TMT at high pressure superheating section and dilution steam bank coils; refer Figure 2 and Table 1 for detailed results. During the test run a total furnace feed in Zone-A and Zone-B was 29.4 tph against design feed rate of 29 tph (14.5 tph each furnace); this corresponded to 20% in-

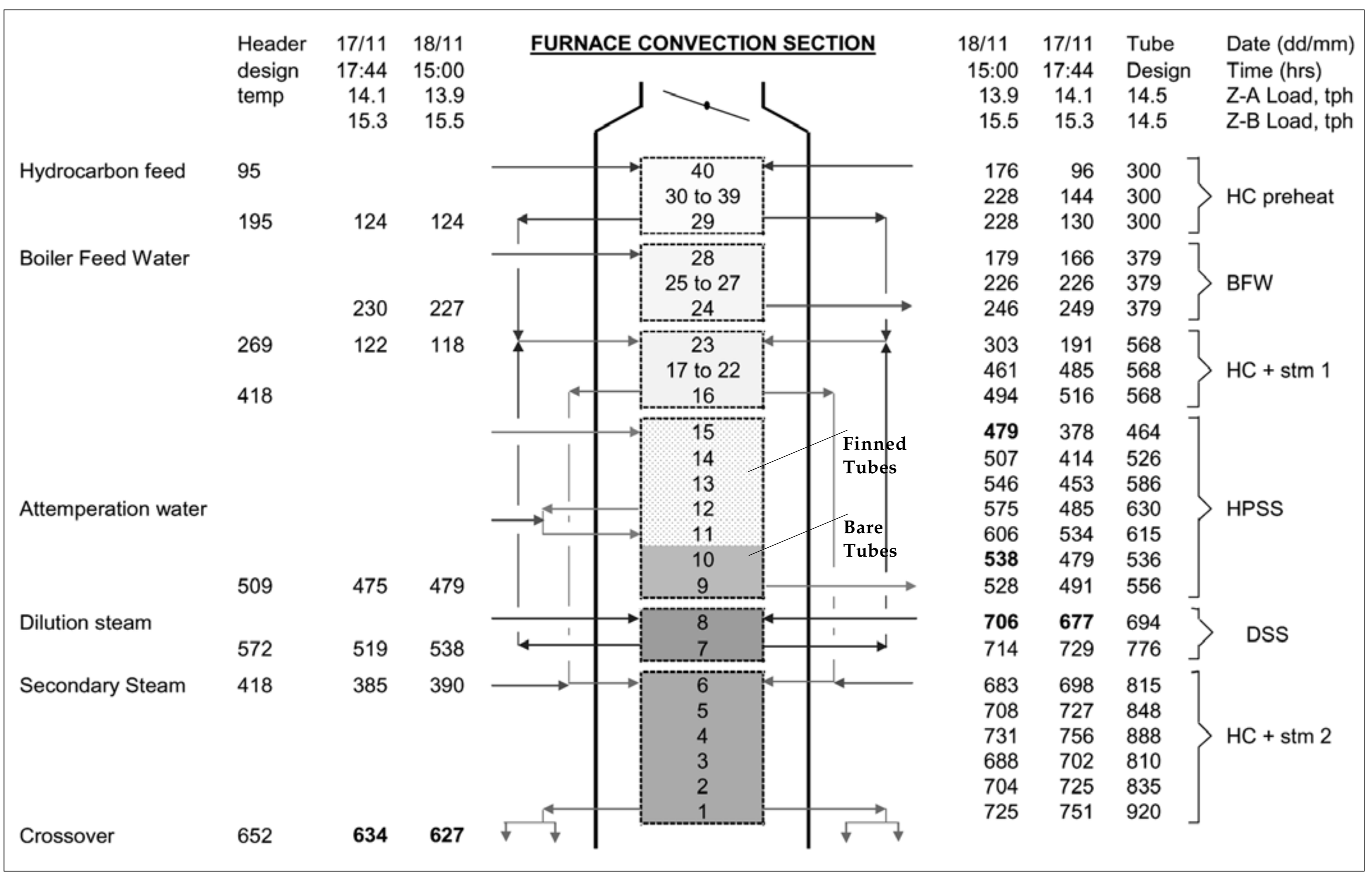

Figure 2: Furnace convection section model output

Table 1: SHPSS bank and Dilution steam bank tube row TMT

Section and Tube Row	Design TMT, degC	17/11 TMT, degC	18/11 TMT, degC
SHPSS Bank			
Tube Row No.15	464	378	479
Tube Row No.14	526	414	507
Tube Row No.13	586	453	546
Tube Row No.12	630	485	575
Tube Row No.11	615	534	606
Tube Row No.10	536	479	538
Tube Row No.9	556	491	528
Dilution Steam Bank			
Tube Row No.8	694	677	706
Tube Row No.7	776	729	714

crease in processing capacity. The field observation showed that air flow limit was simultaneously reached (excess oxygen 1.5% in flue gas) as air registers of individual burners and stack damper were almost fully open at this high throughput condition.

Further to this study and test run, FRNC runs were undertaken to check the feasibility of introducing steam flow to the HC+steam2 coils. Based on the result of this feasibility study, it was recommended to start steam flow to HC+steam2 coil to control skin temperatures in the convection section to reduce the skin temperatures in the upper sections.

Inferences of the Modeling & Analysis Study

- Average increase in furnace throughput in both the furnaces was 20%.
- Bottlenecks for the enhanced capacity case were identified to facilitate further debottlenecking
  - Throughput limited by tube skin temperatures of HPSS and dilution steam bank tubes in the convection section.
  - Air flow limit was simultaneously reached as air registers of individual burners and stack damper almost fully open.
- Introduce steam flow to HC+steam2 coil to control skin temperatures in convection section to reduce the skin temperatures in the upper sections
- Benefits ---> Increase in processing capacity during decoking of one furnace was in the range of 3 MMUSD per annum.