1. Introduction

A hydrocracker consisting of two separate reactors configured in series has five reaction beds in total. In the reaction beds, heavy components present in the feed are broken down or cracked into lighter components assisted by the presence of added hydrogen gas and a catalyst. The major products from hydrocracking are jet fuel, diesel, naphta fractions and LPG.

To control the reaction, the temperature at the inlet of each bed is controlled by "quenching" the reaction mixture with cold hydrogen. The goal is to control an average weighted bed temperature, since this is directly related to the reaction efficiency and product composition.

A simplified process diagram with the primary control loops is shown in Figure 1. As can be seen, the reactor effluent exchanges heat with the feed before it enters the furnace, causing an important interaction between inlet and outlet of the process.

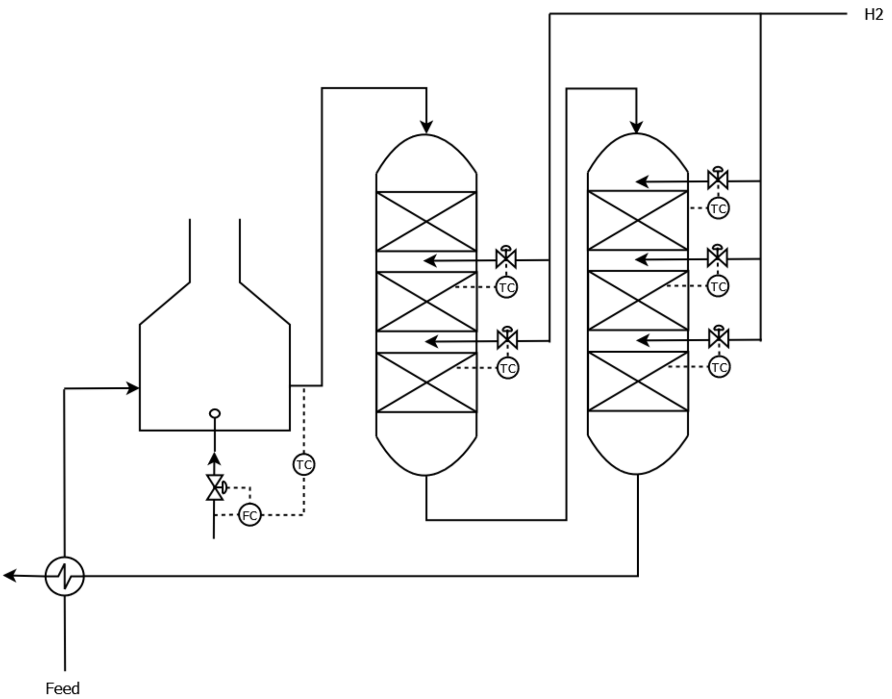

Figure 1: Simplified Process Flow Diagram

By nature of the process, the six temperature controllers are highly interactive. The tuning of each impacts the behavior of the other loops. The heat integration between reactor effluent and fresh feed only compounds this problem. Any disturbance at the inlet that is not rejected by the temperature controllers will be propagated back to the inlet about one and a half hours later (=residence time in the reactors).

The tuning is also impacted by the degraded performance of the hydrogen quench valves. Each valve was shown to have stiction of about 0.5%. This stiction causes the hydrogen flow passing through the valve to move discreetly, with steps of about 2-3 t/h in the low valve opening range (<40%) up to 8-10 t/h in the high valve opening range (>50%).

2. Tuning Project Methodology

Before the project, the average weighted bed temperature of the second bed, where the majority of the reaction is happening, was oscillating with a period of about 20 minutes and an amplitude of 1.5 degrees C.

The project was executed in a structured and sequential manner:

- Historical data analysis was done to assess the current state and pinpoint the possible sources of the oscillations, as well as to quantify the valve issues.
- These assumptions were checked on the process by putting specific loops in MAN mode and follow the response of the process.
- Dedicated step tests were executed within the feed strategy imposed by planning.
- Tuning parameters were calculated by usage of AptiTune and engineer's experience

It was found that each valve has indeed issues that are too big to overcome with only tuning. Especially the valve of the second bed of the second reactor causes problems, causing sizeable process disturbances that can be mitigated but not completely rejected by the third temperature controller of the second reactor.

This means there will always be carryover to the inlet of the process (through the heat exchangers), thus it is crucial to calculate robust tuning to avoid oscillations that can potentially become unstable, as has been seen in the past.

3. Results

The result of the tuning effort on the most important process variable, i.e. the weighted bed temperature of the second reactor, is shown in Figure 2. The two main elements to observe are:

- The amplitude of the oscillations has decreased by more than 40%.
- The period between peaks has been increased by a factor of almost 2.

Because of the valve issues, the amplitude can't be reduced further since it corresponds to the effect 8-10 t/h hydrogen steps have on the average temperature as described in the problem definition.

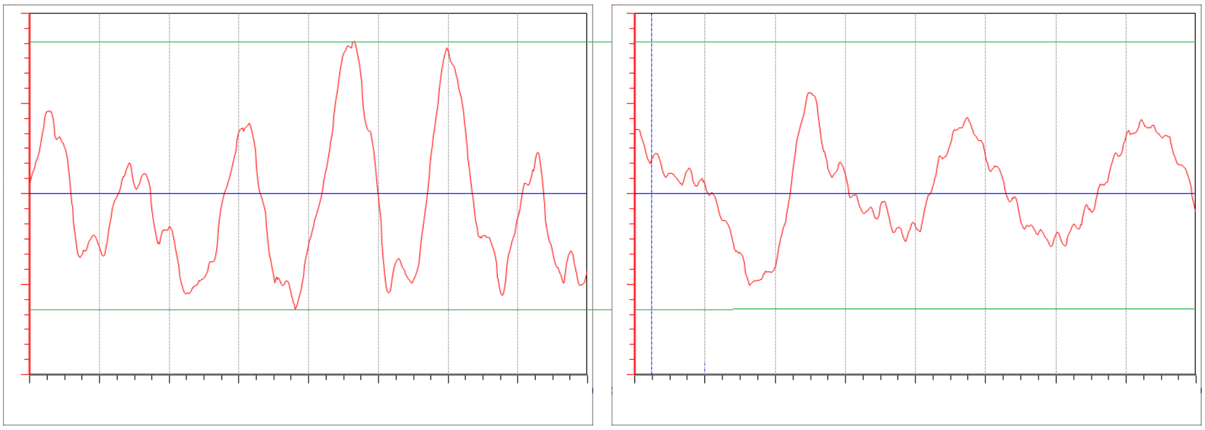

Figure 2: Before (Left) and After (Right) of the Weighted Average Bed Temperature of the second reactor.

Overall, the better control of the average weighted bed temperature means the disturbances that need to be handled by the downstream fractionating column have been reduced significantly. This means the operators have to do far fewer interventions on this column, product qualities vary less over time and higher feed rates are achievable.

There is also a positive impact on the pressure controller of the hydrogen header. In the past, hydrogen had to be vented to the atmosphere regularly to maintain pressure control as a result of the oscillations on the hydrocracker. These events have been greatly reduced with the new tuning. The benefit associated with the reduced hydrogen loss is in the range of $1.000.000/year.

4. Conclusion

The tuning of the hydrocracker hydrogen quench valves was difficult because of the

- Highly interactive process with a link between inlet and outlet.
- Degraded valve performance severely impacting process control.

IPCOS has been able to overcome these issues and deliver a solution to the client that achieved the goals set at the project kick-off. The main takeaways are:

- Robust tuning was calculated and implemented that should prevent process runaway.
- Temperature oscillations have been reduced, resulting in more constant product quality, greatly ameliorating the downstream column operation
- **Hydrogen losses have been minimized resulting in a significant benefit for the client, in the range of $1.000.000/year.**