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Micro Motion Meters Used to Close the Material Balance for a Refiner's Fluid Catalytic Cracking Process

Overview

A major refinery in Eastern Europe used Micro Motion meters to improve the mass balance at its FCCU. The refiner wanted to improve the mass balance, since important decisions regarding the operation of the unit are based on mass balance accuracy. These decisions include: catalyst additions and selection, feed throughput versus conversion, feed purchases, downstream processing, capital projects, post auditing projects, modeling, and optimization of advanced controls. Studies have shown that an improved mass balance can result in optimized operations, which have an economic impact of several million dollars per year.

Challenge

The refiner had incurred an FCCU material balance of 96% using orifice plate DP measurements. The target was 99%. The refiner tried recalibrating the DP transmitters and correcting temperatures, pressures, and flowing gravities, but he was still unable to get consistently accurate results.

Since there was a poor weight balance, the refiner had difficulty making sound operational decisions. In addition, the plant optimization software required an accurate balance in order to function properly.

Solution

To upgrade the flow measurement system, the refiner installed nine Micro Motion meters to measure the primary feed and product streams for his 56,000 BPD FCCU. One vortex meter was used to measure a 550 °F (288 °C) stream on an 8-inch line (203 mm) and one turbine meter on a 12-inch (305 mm) low-pressure gas stream. Figure 1 shows a simplified schematic of the unit.

Benefits

With the new flowmetering system, the refinery was able to improve the mass balance accuracy from 96% to 99.5%. The refiner knew that he now had accurate flow data on the unit. This means the conversion, yield, and catalyst selectivity he calculates is accurate and reliable. If he changes process conditions on the unit or the feedstock, he could evaluate the correct impact on the unit. In addition, if he decided to invest in a new piece of capital equipment such as a new feed distribution system or new reactor internals, he could post-audit the project.

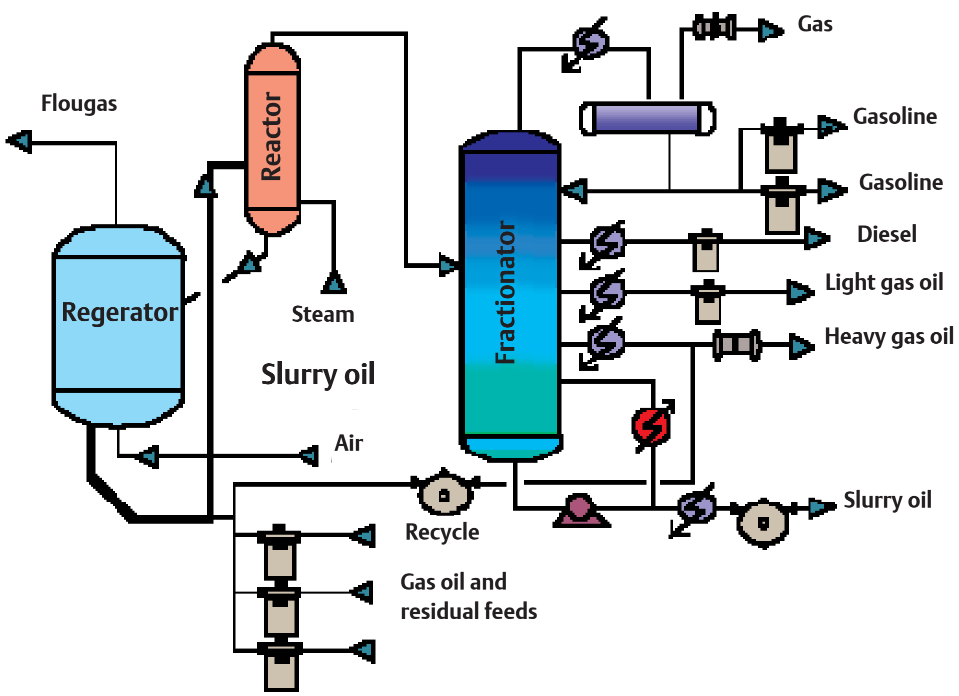

Figure 1. Simplified schematic of flowmeters used on FCC process

Improving the mass balance was the primary goal in installing the Micro Motion meters, but reducing the maintenance of the heavy oil streams was also important. The refiner had consistent maintenance problems, including plugging of the impulse lines from the DP transmitter and erosion on the slurry stream. With the non-intrusive design of the Micro Motion flowmeter, the maintenance problems were eliminated.

Most of the meters are configured to read flow as well as density. Feed-stream density measurement is used for feed-forward control to indicate when the feedstock composition is changing. This enables the refiner to make changes to process conditions before an upset is experienced.

With dependable, accurate data, the refiner can now effectively evaluate operation of the FCCU and make the operational changes and capital investments required to maximize the profitability of the process unit.

Improved mass balance leads to higher profitability

To understand the economic impact that an improved mass balance would have on the profitability of an FCC unit, Refining Process Services (RPS) conducted a study. The study clearly demonstrates how inaccurate mass balances can, and often do, lead to erroneous operating decisions and loss of profitability.

The study analyzed the impact of inaccurate flow measurement on operating decisions for the unit. In the example, the FCC process engineer must decide whether to increase unit operating severity (increased conversion) or to increase fresh feed rate to some unit constraint or limitation. Typical FCC yield shifts and the resulting FCC economics for these two operating options are shown in Table 1.

The base case represents typical yields for a 52000 BPD FCCU cracking gas oil feed at a 990 °F (532 °C) riser outlet temperature. Since the unit was not constrained at the base case operation, the unit engineer had the option to either increase the cracking severity or the fresh feed rate up to some unit limitation. In this particular example, the limit was the wet gas compressor load. Case 1 shows the yields and profitability resulting from increasing the cracking severity by increasing the riser temperature to 1000 °F (537 °C). Increasing conversion to the wet gas compressor limit increased product value by 0.73 \$/BBL feed or 12.56 MM\$/year.

Alternatively, the feed rate could be increased until the wet gas limit is attained. As shown in Case 2 on Table 1, the feed rate could be increased by 1700 BPD before reaching the wet gas limit. Although there is very little change in the yield distribution relative to the base case, the increased feed rate will generate an additional 14.72 MM\$/year in profit.

All three cases shown in Table 1 assume 100 wt% mass balance as well as completely accurate flow meters. Obviously, in this case, the refinery LP or specific FCC model will dictate increasing the feed rate rather unit conversion to maximize unit profitability.

Table 1. FCC Unit Yields

Case	*Base*	*1*	*2*
Feed Rate, BPD	*52000*	*52000*	*53700*
Riser Temp. °F	*990*	*1000*	*990*
Wet Gas, MSCFH	*1764*	*1821*	*1821*
Yields	*Wt. % (Vol. %)*	*Wt. % (Vol. %)*	*Wt. % (Vol. %)*
H2S	*0.05*	*0.05*	*0.05*
H2	*0.16*	*0.16*	*0.16*
C1	*1.63*	*1.79*	*1.63*
C2=	*1.17*	*1.24*	*1.18*
C2	*1.27*	*1.36*	*1.27*
TOTAL C2-	*4.28 (5.25)*	*4.60 (5.62)*	*4.29 (5.27)*
C3=	*4.34 (7.59)*	*4.45 (7.78)*	*4.32 (7.56)*
C3	*1.47 (2.65)*	*1.54 (2.76)*	*1.46 (2.63)*
IC4	*3.21 (5.21)*	*3.20 (5.19)*	*3.17 (5.14)*
NC4	*1.95 (3.04)*	*1.97 (3.07)*	*1.93 (3.02)*
C4=	*5.34 (7.99)*	*5.40 (8.08)*	*5.37 (8.04)*
Gasoline	*49.49 (61.03)*	*49.32 (60.83)*	*49.41 (60.94)*
LCO	*15.51 (15.05)*	*15.59 (15.08)*	*15.58 (15.14)*
Slurry	*9.05 (8.06)*	*8.52 (7.56)*	*9.11 (8.11)*
Coke	*5.35*	*5.41*	*5.34*
Total	*100.00 (115.87)*	*100.00 (115.97)*	*100.00 (115.85)*
Profit MM\$/Year	*Base*	*+12.56*	*+14.72*

In the real world, while the refiner may report a material balance of 100 wt%, the flowmeters are usually not completely accurate. Conventional orifice plates and anubars may be in error by 1 - 2 %. As an example of the impact on unit profit, assume that for Case 1 in Table 1, the product flowmeters measured the slurry oil too low and the gasoline too high. In this example, the flow measurement errors are small, affecting the slurry oil and gasoline by only 0.5 wt% each. As shown in Case 3 on Table 2, even though the yield shifts are small, the impact on the unit economics and profitability could lead to the wrong decision from the unit model or refinery LP, since Case 3 shows a slightly higher profitability than Case 2.

The problem could be compounded if there was also an error in the measurement of the fresh feed rate. Case 4 in Table 2 shows the impact on the economics if there is a 1% error in the feed rate measurement for the operation of Case 2. Instead of the true feed rate of 53,700 BPD, the rate is measured at 53,200 BPD. While this error does not significantly affect the yield distribution (since the yields are all normalized to 100 wt% recovery), the apparent profit would be 13.54 MM$/year relative to the base case instead of the 14.72 MM$/year actual profit. The combination of small errors in flow measurement described in Cases 3 and 4 would lead to the erroneous conclusion that raising the riser temperature would increase profitability by about 1.36 MM$/year more than raising the feed rate.

This is just one example of how small errors in flow measurement will lead to a mistake in decision making, unit optimization, and loss of profit. It should be noted that as more refiners rely on advanced control systems and on-line optimization techniques, yield measurement accuracy becomes even more critical. Unit yields are used continuously in this system to drive the unit operations to an economic optimum. Any yield measurement errors will make it very likely that the unit will be driven to a false optimum, causing a substantial loss in profits, which could easily amount to millions of dollars per year.

Figure 2. Two parallel D300 sensors on FCC gasoline

Table 2. FCC Unit Yields

Case	*3*	*4*
Feed Rate, BPD:		
Actual	*52000*	*53700*
Measured	*52000*	*53200*
Riser Temp.°F	*1000*	*990*
Wet Gas, MSCFH	*1821*	*1821*
Yields	*Wt. % (Vol. %)*	*Wt. % (Vol. %)*
H2S	*0.05*	*0.05*
H2	*0.16*	*0.16*
C1	*1.79*	*1.63*
C2=	*1.24*	*1.18*
C2	*1.36*	*1.27*
Total C2-	*4.60 (5.62)*	*4.29 (5.27)*
C3=	*4.45 (7.78)*	*4.32 (7.56)*
C3	*1.54 (2.76)*	*1.46 (2.63)*
IC4	*3.20 (5.19)*	*3.17 (5.14)*
NC4	*1.97 (3.07)*	*1.93 (3.02)*
C4=	*5.40 (8.08)*	*5.37 (8.04)*
Gsaoline	*49.82 (61.45)*	*49.41 (60.94)*
LCO	*15.59 (15.08)*	*15.58 (15.14)*
Slurry	*8.02 (7.11)*	*9.11 (8.11)*
Coke	*5.41*	*5.34*
Total	*100.00 (116.14)*	*100.00 (115.85)*
Profit MM$/Year	*+14.90*	*+13.58*

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