Raman composition analysis of gas turbine fuel feeds

Benefits at a glance

- Provides fast, accurate, non-destructive composition analysis of gas turbine fuel feed composition
- Protects and optimizes gas turbines by delivering results in time to make critical operational changes
- Is tailored to meet specific fuel feeds or developed to handle a wider range of fuel compositions and blends
- Delivers quicker updates with far higher uptime than conventional separation-based analysis methods such as GC and MS
- Provides future-proof measurements for carbon-free fuels, such as hydrogen and ammonia
- Measures hydrogen from below 1% to levels approaching 100% using a single analyzer

Introduction

As the world shifts toward decarbonization, the fuel flexibility of gas turbines is being embraced as a way to reduce carbon emissions in the energy ecosystem. Modern heavy-duty industrial turbines have been designed to accept a much wider range of fuel blends. Many companies around the world are turning to gas turbine manufacturers to ask if it is possible for their existing turbine assets to burn hydrogen-rich fuels. Customer demand is for fuels ranging between 5% and 50% H_2, and there are dozens of installed gas turbines running on fuels containing hydrogen today.[1]

To use a new or non-traditional gaseous fuel in a gas turbine, it is essential to understand the fuel composition to determine the heating value and the Modified Wobbe Index. This information allows the fuel to be matched to the appropriate combustion system and conditions.[2] For low NO_x and low emissions turbine designs, which demand better fuel conditioning, it is particularly important. Composition measurements allow the calculation of the hydrocarbon dewpoint, critical to avoiding condensate that can result in burner *coke up*. In addition, hydrogen blends create a higher probability of flashback if the combustion conditions are not adjusted to accommodate the properties of the blended fuel.

Some gas turbines are shipped with multiple analyzers to perform fuel composition measurement, including gas chromatographs (GCs) which result in long lag times and increased risk. In one study, a 3-hour fuel heating value analysis was conducted at a site that had periodic fuel variation.[3] Compositional analysis was conducted using a GC with a measurement cycle of 180 seconds. Within the survey period, there was a transient event in fuel composition that occurred faster than the capability of the GC to measure and report the change. Two complete cycles (6 minutes) passed before the transient was detected, which would pose an increased safety risk for operation of a turbine.

Benefits of Raman analyzers

Raman spectroscopy helps to future-proof gas turbine fuel systems by providing real-time, reliable composition analysis of gas turbine fuel feed, including standard hydrocarbon fuels, ammonia, and fuels blended with up to 100% hydrogen. Raman spectroscopy is an ideal tool for analyzing the composition of rapidly changing and blended fuel. It is non-destructive, can be tailored to meet specific fuel needs, and can handle a wide array of fuel blends without changing any system components.

Experimental

An extended evaluation of a Raman gas-phase analyzer to monitor turbine fuel feed was undertaken at a power gas turbine technology laboratory. The owner of this site typically shipped four different analyzer technologies with each turbine, including a calorimeter, a redundant pair of gas chromatographs, an oxygen analyzer, and a CO_2 analyzer. The primary goal of this evaluation was to compare mass spectrometry (MS) and Raman spectroscopy for measuring rapid transient events in fuel blending, including hydrogen and ethane blended into natural gas. A secondary goal was to determine if a single analyzer could replace the suite of four analyzers for this measurement.

Results and discussion

The Raman analyzer was integrated with the gas fuel stream by means of a bypass to a Raman fiber optic probe mounted in a simple union cross interface. Measurements were made at the fuel feed pressure of 350 psia. The mass spectrometer required sample transfer lines and sample conditioning prior to the injection port.

ⓘ All Raman analyzers and probes referenced in this application note are Endress+Hauser products powered by Kaiser Raman technology.

Extensive studies of rapid transient events were undertaken with both analyzer systems. In one set of tests, hydrogen was spiked into natural gas at levels between 25 and 70 mol % over a period of 40 seconds, then stepped back down to ~24 mol % over another 40 seconds. Figure 1 depicts how both the Raman and MS analyzers performed during this test. Raman data was updated every 13 seconds and was able to follow the transient event. The mass spectrometer reports data approximately every 2 seconds. Despite having a faster cycle time, the mass spectrometer had a severe lag due to the sample conditioning system.

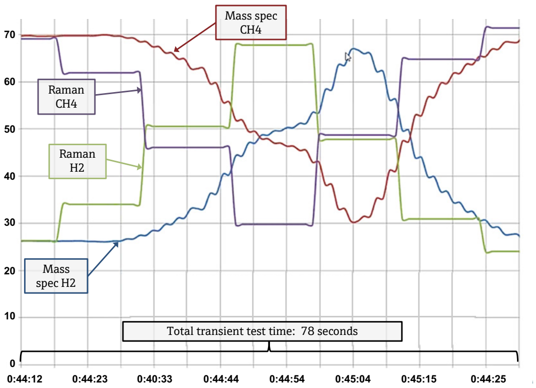

Figure 1: Raman and mass spectrometer analysis of hydrogen spiked into a natural gas stream

Figure 2 shows the results from MS and Raman measurements as ethane is spiked into natural gas during a 1-hour test. The plot also includes the results from the proprietary flow algorithm developed by the facility, which was used as a baseline. The Raman analyzer was readily able to follow the transient event of blending ethane into natural gas, with results closer to 'flow based' results than the MS. The MS system exhibited an uptime of only 67% during the experiment, whereas the Raman system demonstrated a 100% uptime. Similar results were observed during other experiments. Over an 8-week period of the evaluation, the Raman analyzer did not require recalibration, and it continued to provide fast and accurate results. At the end of the evaluation, feedback indicated that the Raman analyzer was found to be a reliable, accurate, and steady technique for gas turbine fuel feed composition analysis, during both steady-state and transient events. As a result, the Raman process analyzer was approved by the facility and its owner as a suitable GC replacement for turbine fuel feed measurements.

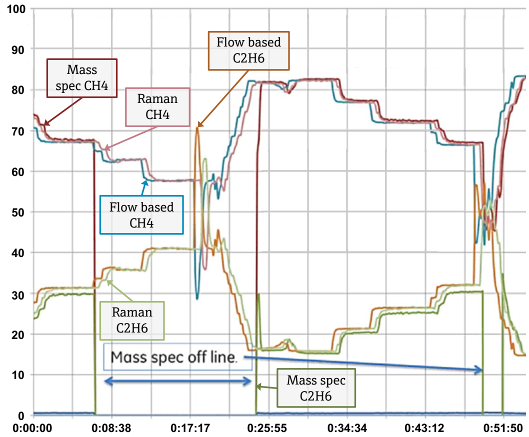

Figure 2: Raman and mass spectrometer analysis of ethane spiked into a natural gas stream

Conclusions

The results of this study demonstrate that Raman analyzers are an extremely effective composition measurement tool for a wide range of fuels used to power gas turbines today. Raman systems are future-proof when it comes to including new and upcoming fuels, such as hydrogen and ammonia, that can be used as carbon-free fuels for turbine and internal combustion engines.[4] Raman systems offered by Endress+Hauser (powered by proven Kaiser Raman technology) can be easily tailored to meet the measurement needs of specific fuel feeds. Typically, all that is required to measure a new fuel or blend is to update a software method or model and recalibrate the analyzer on an appropriate calibration gas blend for the new composition. The hardware does not need to be updated or replaced. As the decarbonization movement gains speed around the world, fuel-flexible gas turbines and Raman-based measurement systems should play prominent roles in the new emerging energy ecosystem.

References

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