
Analysis of methane as energy fuel – operational issues

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ABSTRACT

Issues that are related to the operation of cogeneration generators that are powered by gas engines that use mine gas as a fuel are presented. Gas engines are increasingly being used to drive electric generators; in such an application, gas is used as a fuel, whether it is mine gas, coke oven gas, septic tank gas, or mains natural gas. In an area where coal is mined, mine gas is commonly used as a fuel to power combined heat and power (CHP) generators. The use of mine gas as a fuel is highly desirable – both for environmental and economic reasons. The benefits and difficulties of using this gas as a fuel are presented.

Keywords: power systems, environmental protection facilities, process control, computer applications in engineering

1. Introduction

Over the years, gas engine-driven cogeneration units that use mine gas as a fuel have been installed in district heating and CHP plants. The first such installations produced electricity and heat in cogeneration, thus reducing the combustion of gas in gas-fired boilers or adapted water boilers. The engines that were built in a heat plant could be trigeneration units, producing cooling energy for the air-conditioning system of the mine workings in addition to electricity and heat. The gas installations of these engines require a gas that is better purified than those of the boilers; however, gas purification is carried out by filters that are built into the gas engine installations. The gas that is fed into a gas engine flows first through a paper gas filter, which removes dust, sand, and rust; at the next stage, it passes through a non-woven filter that was designed to remove impurities that are not caught in the general filter. To a lesser extent, contamination of the fabric and paper filters also causes reduced engine performance and problems with starting. In the long term, oil contamination through the gas-treatment system into the fuel supply path causes contamination of the flame arresters, which are built inside the cylinder heads. Contamination of the paper and fabric filters necessitates shutting down the engine, but the filter-replacement procedure itself ranges from 30 minutes (for fabric filters of gas paths) to 120 minutes (when replacing paper filters). On the other hand, the fouling of the flame arrestors involves a longer engine shutdown; the procedure for removing contaminated flame arresters itself requires the disassembly of the entire fuel supply system to the cylinders. Cleaning the flame arresters is also a lengthy process; if a set of clean interrupters is available, the repair time is shorter. As an example, the cleaning time for an engine intake system can be as high as about 200 man-hours, using a set of remanufactured (i.e., chemically cleaned) interrupters (Moran et al. 2014).

2. Gas composition analysis

From the beginning of the gas network operation, the composition of the mixture was monitored only in terms of the concentration of pure CH_4 in the mixture. The methane content in the mixture was measured with stationary methane meters at the mine demethanation facilities and at the individual plants that consumed mine gas. In addition, the CH_4 content of the mixture was measured three times a day (and even more frequently if necessary) with hand-held methane meters. Since 2014, the gas composition has been monitored at individual intakes and offtakes nonstop using chromatographs. This solution makes it possible to determine the gas quality and the variability of its composition very accurately over any time horizon. As part of the analysis of mine gas quality (in terms of the content of pure methane in the mixture), the concentration of methane was examined at the intake with the lowest average concentrations and the intake with the highest methane contents. The selected CHP plant was taken as the gas offtake point.

Analyzing the results, it can be seen that a great difference in concentration in the intake of up to 30% does not significantly affect the quality of the gas in the source, where the average concentration in 2019 was 54.3%. Intakes that have a decisive influence on the quality of the mixture that is supplied as fuel for gas engines were selected for the analysis. Figure 1 shows that the concentration of the JasMos intake is quite stable at around 70%, while the concentration of the Pniówek intake is significantly lower and has greater variability. However, it can be assumed that such changes in the concentrations in both intakes are significantly influenced by the exploitation of the deposits.

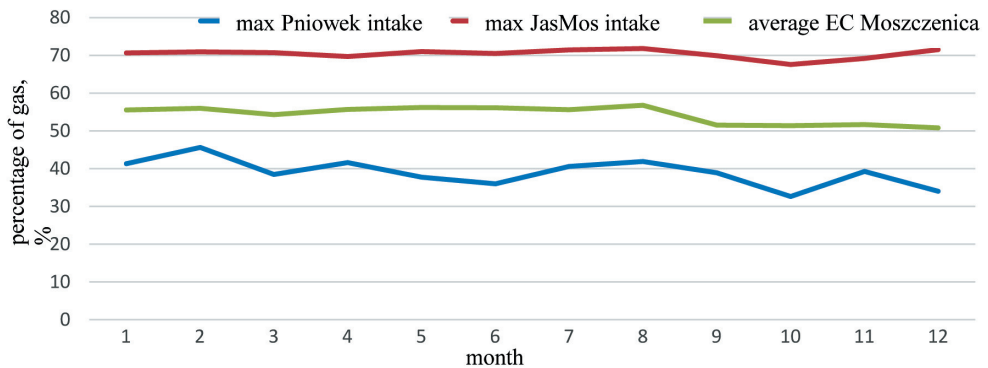


Fig. 1. Graph of methane concentration variation in 2019 depending on intake

Figure 2 shows the proportion of gas with a concentration above 60% of pure CH_4 in the mixture; this value averaged around 40% in the year under review. This 40% is a gas with a fairly constant composition and low dynamics of change, which has a strong influence on the stable composition of the gas mixture from the different intakes.

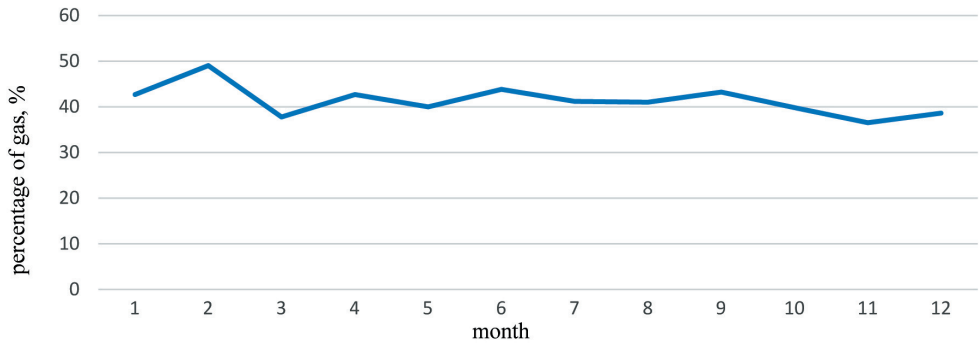


Fig. 2. Graph of percentage of gas with concentration above 60% in mixture

From Figure 3, it can be observed that, on September 5, 2019, one of the lowest gas concentrations was recorded in the gas engine feeder pipeline (i.e., 38.1% of methane in the mixture). This was an instantaneous value and did not cause any anomalies in the operation of the gas engine – the engine load was 100%, and the throttle opening ratio was 71% (a value that was as correct as possible). The only visible change in the engine performance with the changes in the concentration was the periodically changing amount of gas that was burned.

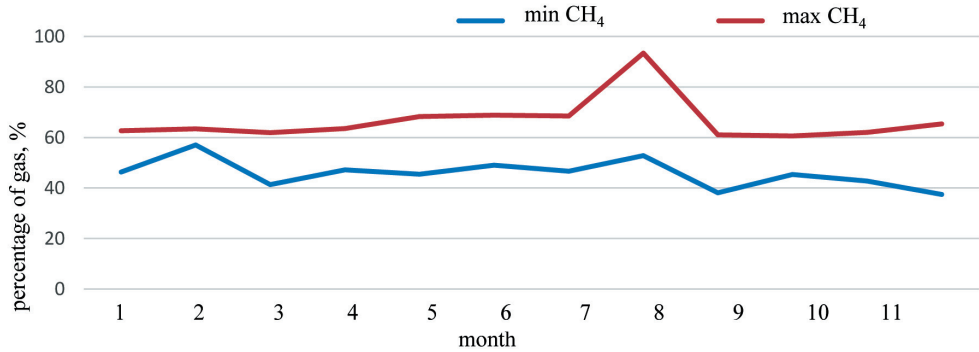


Fig. 3. Min and max concentrations on supply in 2019

3. Analysis of engine operating parameters

Figure 4 shows a graph of the engine load [kWe] and throttle opening rate [%]. The graph covers the period before replacing the filters in the gas paths to the individual cylinder rows. It can be seen that the load before and after the replacement of the filters remained at a level around 95–100%, and the throttle opening ratio was even higher than before after the replacement of the filters. The filters were changed six times in 2019; each time, there was no visible change in the parameters before and after the filter changes.

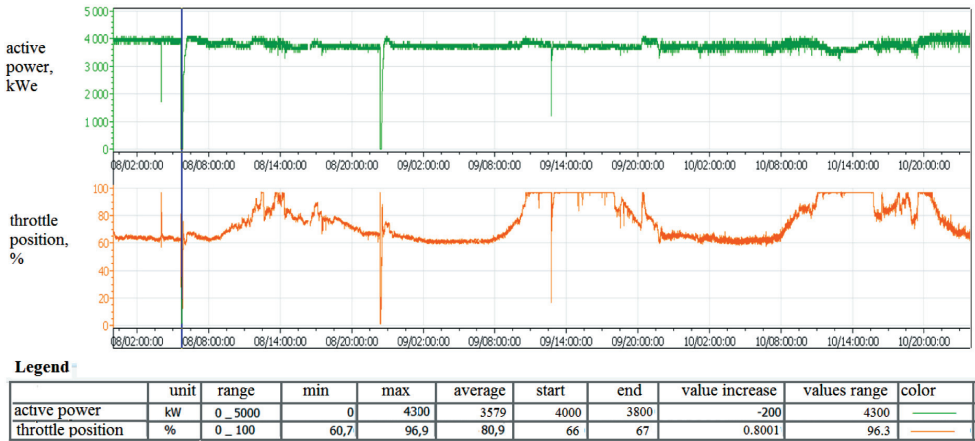


Fig. 4. Comparative graph of engine load and throttle opening rate after replacing filters on gas paths

The cleaning of the flame arrestors and the engine intake system was performed with a spare set of flame arrestors (a set of flame arrestors that were already used but after chemical cleaning). The required downtime for such an operation was from November 15–23, 2020, from 8:00 a.m. to 4:00 p.m., which totaled of 200 engine operating hours. During this downtime, turbocharger inspections were also performed.

Another service treatment that was related to the quality and contamination of the gas fuel was the cleaning of the engine intake system with the replacement of the flame arrestors. Figure 5 shows the power load of the engine and the throttle opening ratio a significant decrease in the throttle opening for the same power can be seen at first glance.

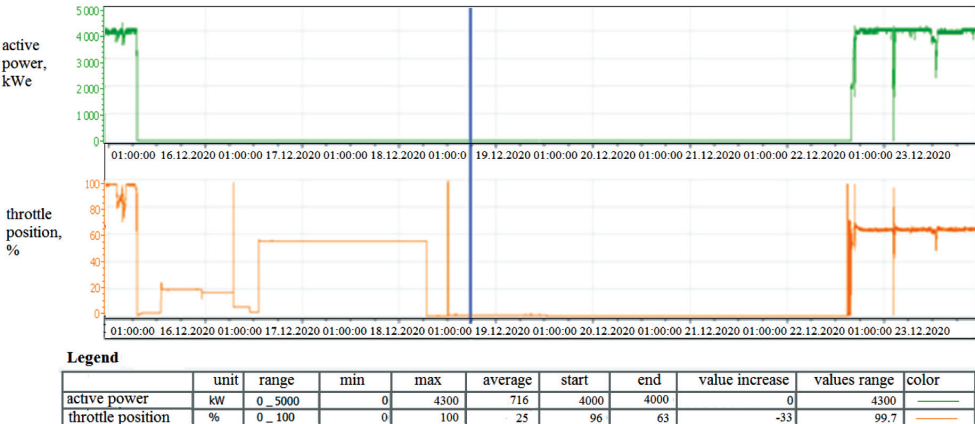


Fig. 5. Comparative graph of engine load and throttle opening rate after cleaning intake system and replacing flame arrestors

Before the engine was put aside for cleaning, it could be seen that it had been running with the throttle opening of between 80 and 100%, and the power was at a level of 90–95% (as shown in Figure 6). A number of adjustment attempts and other diagnostic procedures were carried out, but these did not produce the desired results. The decision to clean the intake system was the correct one. The state of the cleanliness of the intake system is best illustrated in Figures 4–6.



Fig. 6. Comparative graph of engine load and throttle opening rate after cleaning intake system and replacing flame arresters

Summarizing the results of the analyses, the following conclusions can be made:

- Changes in the concentration of the gas on the engine power supply – the changes in the concentration of the gas for combustion did not have a major impact on the operation of the gas engine; the engine control system quickly and efficiently coped with sufficiently over-regulating the engine and maintaining the preset power. The system of several interconnected gas supply sources had a positive effect on the stable operation of the entire gas network. There were no frequent nor abrupt changes in the concentration; if such a situation occurred, these were purely emergency cases.
- Contamination of filters on the gas system – the gas-filtration system perfectly coped with solid impurities; any contamination of the gas filters did not significantly affect the power availability of the engine. If it was necessary to replace the filters, the process was not a lengthy or complicated procedure (even though it required the engine to be shut down).
- Oil-borne impurities – due to the design of the compressors that are used in mine de-metalation facilities, oil-borne impurities enter the gas and, together with the moisture that is condensed from the gas (the pipeline runs along overhead catena-

ries as well as in the ground for the most part), resulted in the formation of impurities in the oil-water mixture; these were not captured by the required filtering equipment. These impurities reached as far as the cylinders, causing a gradual fouling of the flame arresters; this in turn caused a continuous reduction in the engine's power availability during the final stage (Laskowski, Smyk 2020).

4. Summary

Fossil gas is a fairly good fuel for electric power equipment; however, a rather sophisticated technical infrastructure is required to manage it in an optimal way.

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