SafeDewPoint summary of the results 2019-2020

08.03.2021

Summary of the context and overall objectives of the project

Steel mill gases such as blast furnace gas, coke oven gas and basic oxygen furnace gas are used in coke plant, sinter plant, hot blast stoves, power plant and reheating furnaces. During the operation, fuel gas combinations can be changed every 30-60 minutes and the resulting sulphuric acid dew point temperature in the flue gas may vary between 85°C and 150°C. The flue gas temperature is usually fixed 10-20 K above the calculated maximal acid dew point (ADP) temperature to prevent corrosion damage. Thus, valuable energy is lost in the periods with the lower ADP temperature. There is a potential to recover it and reuse for combustion air preheating.

The main objective of SafeDewPoint is to recover waste heat from combustion of steel mill flue gases by dynamic adjustment of the flue gas temperature above the acid dew point. For this, inline monitoring of ADP temperature is required. To prevent damage to the heat exchangers and chimneys in case of the measurement failure, inline corrosion monitoring is needed. Neither ADP nor corrosion rate monitoring has been applied in steel mill flue gases before.

The project objectives are to:

1) Identify boundary conditions for waste heat recovery in steel mill flue gases, in order to provide basis for sensor development and implementation,

2) Develop cost efficient inline acid dew point sensor in order to enable economic waste heat recovery and its wide implementation,

3) Develop inline corrosion probe for the protection of heat exchangers and chimneys during dynamic waste heat recovery,

4) Develop operational strategies and algorithm for dynamic waste heat recovery to enable operational trials,

5) Assess the waste heat recovery potential with the developed system under operational conditions in order to obtain realistic values

6) Evaluate energy and costs saving as well as CO2 reduction potential in hot blast stoves, power plant and reheating furnaces in order to estimate implementation perspectives,

7) Enable waste heat recovery in the European steel industry by the dissemination of the project results

In this project a novel inline ADP sensor is being developed. It is based on weighing of the condensing acid. Furthermore, corrosion probes based on the measurement of resistance of a corroding element are being adapted to steel mill flue gases to reach reaction time < 5 min and lifetime ≥ 6 months. Dynamic waste heat recovery concepts on basis of these measurement signals will be developed and validated in operational tests.

Work performed in 2019-2020

In this reporting period fuel and flue gases at two European integrated steel mills were analysed. To enable transferability of results, three plants with representative flue gases were selected for studies:

1) Hot blast stoves as mono-consumer of blast furnace gas,

2) Reheating furnace as consumer of steel mill gas mixtures,

3) Power plant as consumer of various mixtures of steel mill gases with natural gas and further non-gaseous fuels.

The maximal variations for sulphur in the fuel and the flue gas were observed in the reheating furnaces fired with coke oven gas. There was a clear correlation between the H_2S concentration in the fuel gas and SO_2 concentration in the flue gas. The maximal H_2S concentration in the fuel gas reached 1300 mg/m³. The maximal SO_2 concentrations in the flue gas reached 800 mg/m³.

The SO_3 concentration in the steel mill flue gases varied between 0.1 and 3 mg/m³. The calculated sulfuric acid dew point temperatures varied between 92°C and 115°C. The acid dew point variability shows high potential for the application of online ADP monitoring systems for improved waste heat recovery. Boundary conditions for the development of novel acid dew point sensor and corrosion probes were defined.

Potential installation locations for the sensors were identified (**Figure 1**). Novel acid dew point sensor should be installed in a bypass to the main gas duct, usually before the heat exchangers where the temperatures vary between 200°C and 300°C. For the mounting, a flange of 100 mm and a fan will be required. Corrosion probes can be introduced directly into the gas duct after the heat exchangers and in the chimney where the temperatures are likely to fall below the sulfuric acid dew point. Maximal applicable temperature for the corrosion probes is 350°C.

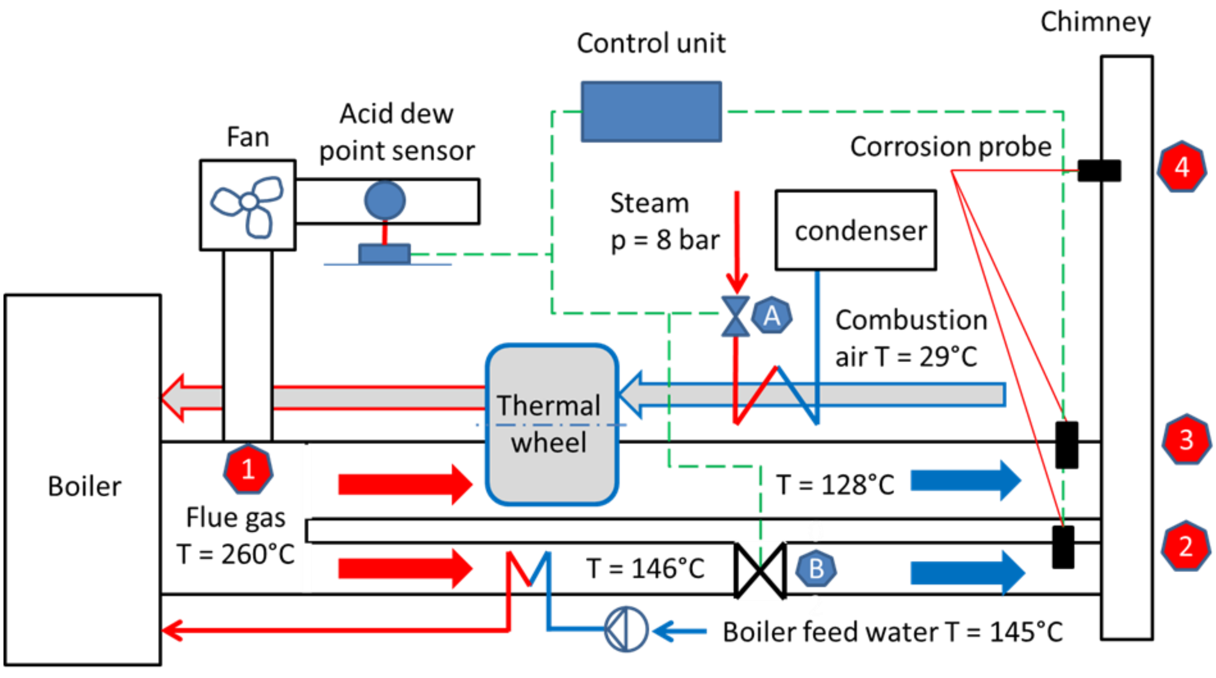

Figure 1: Scheme of potential installation locations in a power plant

For the mounting, flanges with a diameter of 100 mm can be used (**Figure 2**). The working element should be positioned close to the inner wall where the lowest temperatures are to expect. By the definition of the probe length, the thickness of refractory lining on the inner part of the gas duct should be considered. It usually varies between 80 mm and 200 mm. To enable maintenance interval of at least 6 months, nozzles for automatic cleaning of the probe are required. After corrosion alarm is registered and the temperature of the flue gas is adjusted, the condensed acid will be washed down with water or blown off by air in order to prevent the probe damage.

Figure 2: Installation flange in a gas duct

Operational tests with commercially available online ADP sensor by Breen Energy Solutions at hot blast stoves and in power plant were not successful. The ADM-Probe could not measure the acid dew point reliably. The online-values differed considerably from the calculated acid dew point temperatures based on SO_3 and humidity measurements in the flue gas (**Figure 3**). New sensitive measurement system is required to provide online ADP temperature monitoring in steel mill flue gases.

The first tests with a novel acid dew point sensor based on the weighing of the condensing acid (**Figure 4**) were performed under laboratory conditions with water vapour. The measurement cycle analysis showed that the system can register dew point temperature with the help of a weighing cell. Further studies to increase the measurement accuracy will be performed in the next reporting period.

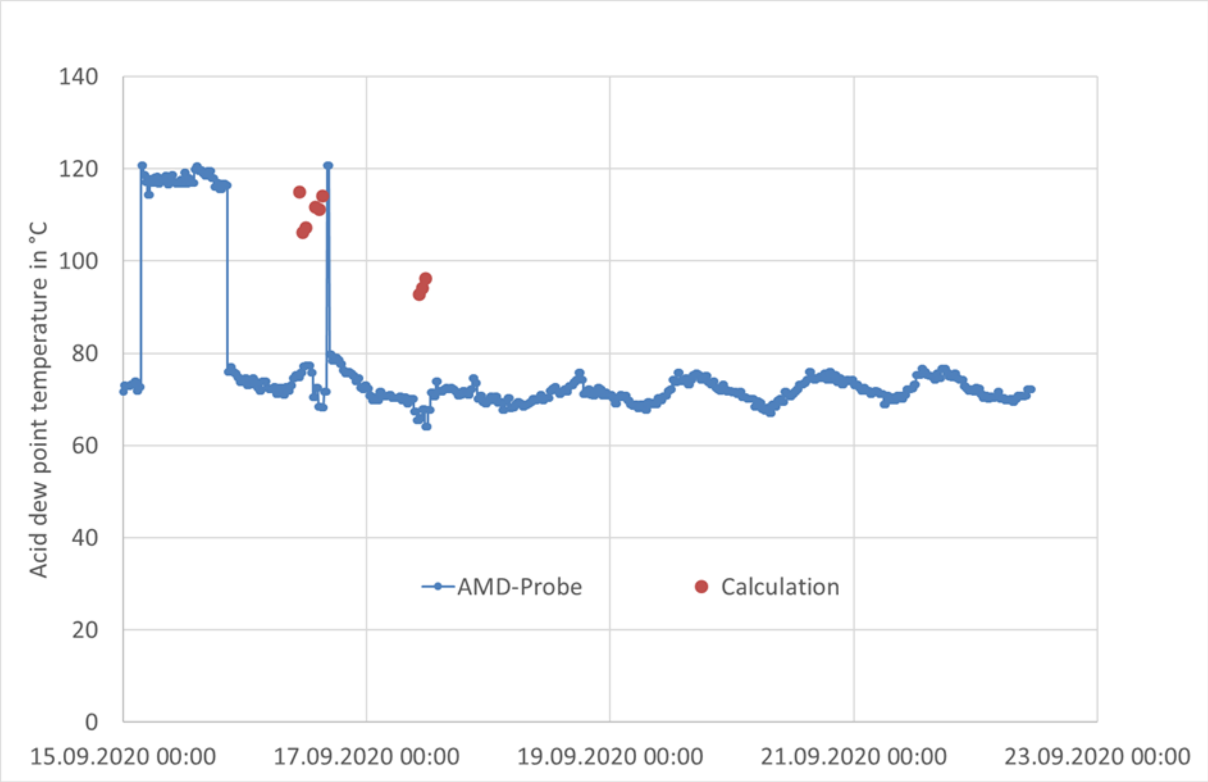

Figure 3: Acid dew point temperatures in a power plant

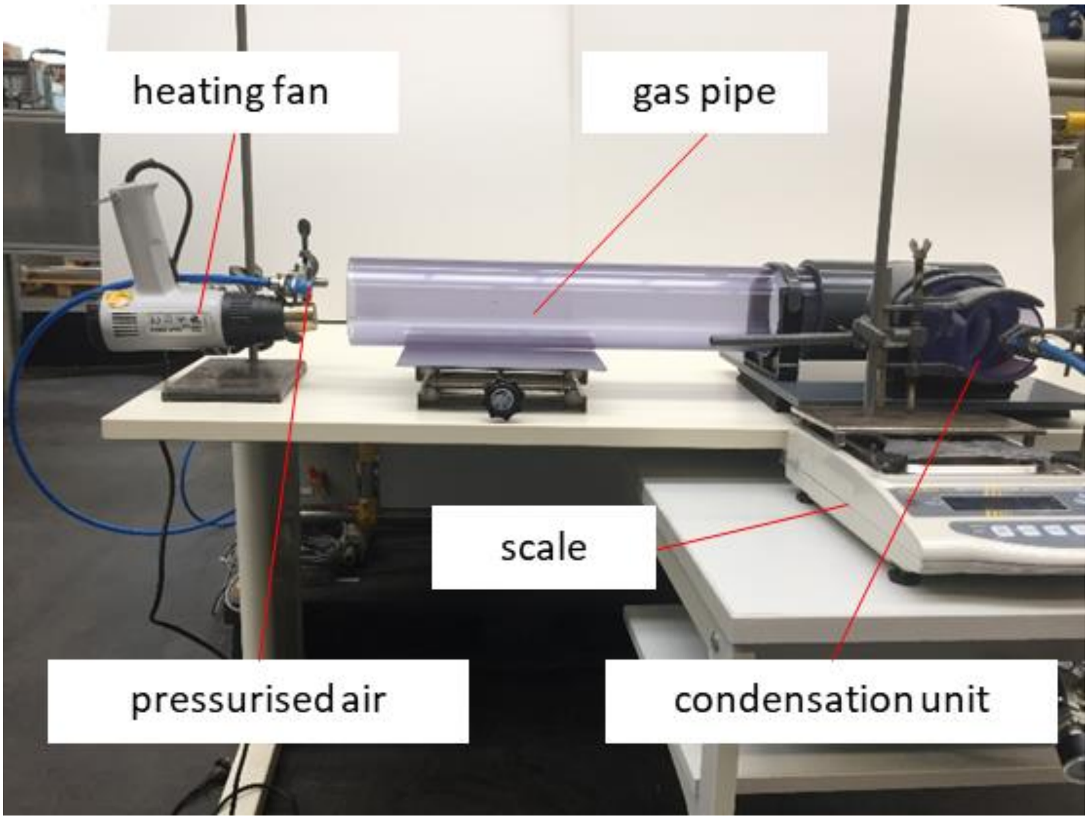

Figure 4: Laboratory test system for dew point measurement

Condensate analysis from the flue gases showed that besides sulphuric acid hydrochloric acid is present. These acids can cause corrosion of chimneys and heat exchangers if the flue gas is cooled below the acid dew point. To protect the equipment, commercially available corrosion probes (**Figure 5**) were tested under laboratory conditions with deionised water and various acid solutions at 110 °C.

Figure 5: Cylindrical carbon steel corrosion probe with a span of 127 mkm

They showed a strong response within 3 minutes after deposition of a single acid drop, while the damage to the probe was minimal (**Figure 6**). This enables equipment protection, and probe lifetime > 6 months seems realistic. Operational tests with corrosion probes will be performed in the next reporting period.

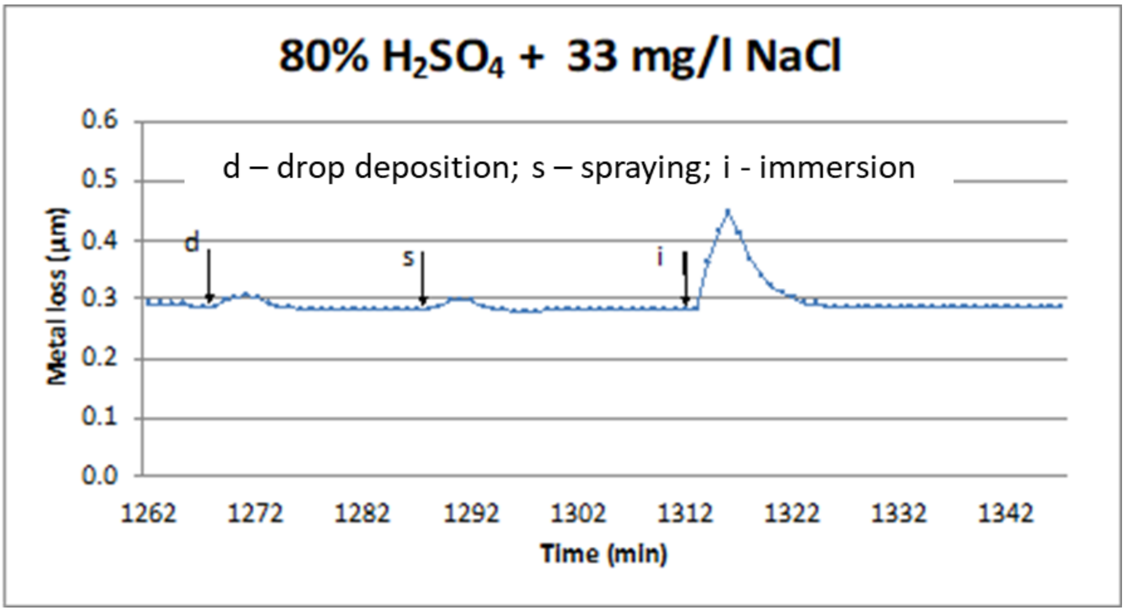

Figure 6: Online signal of the tested corrosion probe during contact with acid

Progress beyond the state of the art

The first systematic study of the acid dew point temperature in the steel mill flue gases showed high potential for the application of online ADP monitoring systems for improved waste heat recovery. Commercially available online ADP sensor by Breen Energy Solutions was applied at hot blast stoves and in steel mill power plant for the first time. The application was not successful. It was not sensitive enough.

Novel acid dew point sensor based on the weighing of the condensing acid is being developed in this project. The first tests showed that the system can register dew point temperature of a water vapour. Further studies to increase the measurement accuracy as well as operational tests will be performed in the next reporting period. Application of this sensor will enable dynamic waste heat recovery and reduce CO_2 emissions.

Advanced high-speed and high-resolution electrical resistance (ER) corrosion probes were tested for the application in steel mill flue gases for the first time. The aim was to increase both parameters over conventional monitoring techniques (coupons, conventional ER). The results are very promising. Due to greater sensitivity and versatility, long-enough lifetime and lower price, cylindrical carbon steel probe is the recommended option for corrosion monitoring of steel mill flue gases. The corrosion probes will enable protection of equipment during dynamic waste heat recovery.

This innovation will enable improvement of energy efficiency of hot blast stoves, power plants and reheating furnaces by dynamic recovery of up to 20% waste heat from the flue gas using existing facilities. For the European steel industry it equals to the savings of 3568 GWh/y or 107 million €/y and emission reduction of 720 $ktCO_2$/y. It will support competitiveness and sustainability of European integrated steel plants.

Contacts

Dr. Pavel Ivashechkin (Coordinator), Dr. Matthias Kozariszczuk
VDEh-Betriebsforschungsinstitut GmbH (BFI), Sohnstr. 69, 40237 Dusseldorf, Germany,
e-mail: pavel.ivashechkin@bfi.de

Dr. Daniel de la Fuente García, Dr. Jenifer Alcántara González
Centro Nacional de Investigaciones Metalúrgicas (CENIM),
Avda. Gregorio del Amo, 8, 28040 Madrid, Spain

Juan José Arribas Ramírez,
ArcelorMittal (AME), C/ Marques de Suances PO Box 90 - Avilés 33400 – Spain

Thomas Lapp
Salzgitter Flachstahl GmbH (SZFG), Eisenhüttenstraße 99, 38239 Salzgitter, Germany