RELEASE OF CORROSIVE GASES UNDER ACTION OF THERMAL PROCESSING OF SOLID CARBON-CONTAINED RAW MATERIALS

RUSLAN AHAIEV, VASYL VLASENKO,
KATERYNA DUDLIA, EDUARD KLIUIEV

M.S. Poliakov Institute of Geotechnical Mechanics of NAS of Ukraine

The actual problem of providing the Ukrainian chemical industry with the necessary amount of gases with the perspective of using alternative sources, in particular thermal processing of solid carbon-contained raw materials was represented in the article. The influence of various components of the gas phase on the corrosion of metallic materials was shown. The process of release of corrosive gases, such as CO_2, O_2, CO, H_2 under action of thermal impact on solid carbon-contained raw materials in the temperature range of 400-900°C was studied. Quantitative data about the gases release and their relation to temperature were presented. The obtained results will help to improve the conditions of gas phase transportation in order to reduce the corrosion effect on metal pipe structures.

Keywords: corrosive gases, thermal processing, gas phase, transportation, carbon-contained raw materials

Introduction. Ukraine has a developed chemical industry, and for the production of chemical products, providing enterprises of the industry with the necessary amount of gases can be an important factor for its effective functioning. So, it is important to diversify gas supplies and have reliable gas suppliers. Currently, the country produces insufficient volumes of process gases to fully satisfy domestic demand and has to import gas to meet its industrial needs. Therefore, in order to solve these extremely important problems, it is important to pay attention to other ways of extracting process gases from alternative deposits.

Formulating the problem. Currently, there is a strategic need to reorient the chemical industry to the use of gases [1] extracted under action of thermal processing on carbon-contained raw materials, which are presented in the form of coal sludge. According to the latest data, there are up to 170 million tons of finely dispersed and high-ash sludge products in sedimentation tanks and sludge accumulators, which occupy an area of about 1,800 hectares [2]. Analysis of the mineralogical composition of such materials showed that the studied samples contain 30-37% organic substances, 61-68% ash, 2-2.2% sulfur and 10-30% clay particles [3]. Therefore, it is worth classifying such man-made deposits as alternative sources of energy. However, until now they are used on a small scale.

The essence of the experimental physical and chemical method of production of process gases consisted in heating without air a certain mass of raw materials with obtaining a solid residue and collecting gaseous and vapor-like products formed in the process of thermal action. Carbon, which was part of the rock mass, was transformed into carbon monoxide and methane, hydrogen into methane and molecular hydrogen, and the degree of such transformations was determined by the rate of chemical reactions according to the Arrhenius law [4].

An important link of this gas production system is an extensive network of pipelines that can be corroded in the presence of corrosive gases during their transportation. One of the main causes of pipe corrosion is the qualitative composition of gases and various polluting components, such as hydrogen sulfide, oxygen, carbon dioxide, etc., which can form aggressive chemical compounds.

Purpose. Therefore, the main purpose of this work is to investigate the processes of gas releasing under action of thermal processing of man-made deposits of solid carbon-contained raw materials and to study the influence of gas composition on the corrosion of gas transportation pipelines.

Results and discussion. Let's consider the influence of various components of the gas phase that cause metal corrosion. The results of studies on the release of corrosive gases CO_2, O_2, CO, H_2 during thermal action on carbon-contained raw materials in the temperature range of 400-900ºC in terms of m^3 per tons including maximum (Max), average (Mean) and minimum (Min) values are shown in Fig. 1.

According to Fig. 1(a), the release of CO_2 rises with temperature increasing in the range from 0.99 to 12.4 m^3/t. At the same time, the maximum value of gas release was observed at a temperature of 900ºC. As we know, carbon dioxide can cause corrosion of metal surfaces in high atmospheric humidity. It can dissolve in water, forming a dissolved form of carbon dioxide, which can react with metal surfaces, in particular with metal oxide or hydroxide on the metal surface, forming metal carbonates. These carbonates are less soluble and form a film that can protect the metal from further corrosion. On the other hand, carbon dioxide can dissolve and destroy protective films that can form on the metal surface under the action of other reagents. This makes the metal more vulnerable to further corrosion.

According to Fig. 1(b), the release of O_2 decreases in the range from 3.80 to 1.27 m^3/t. At the same time, the maximum value of gas release was observed at a temperature of 800ºC. it is well known that oxygen also affects the corrosion of pipes in wet medium and reacts with the metal surface and with water to form metal oxides and hydroxides, respectively, which can lead to the formation of corrosion products such as rust. In addition, most metals create a thin film on their surface that can function as a corrosion barrier. However, oxygen can split this protective film, allowing further contact of the metal with aggressive media.

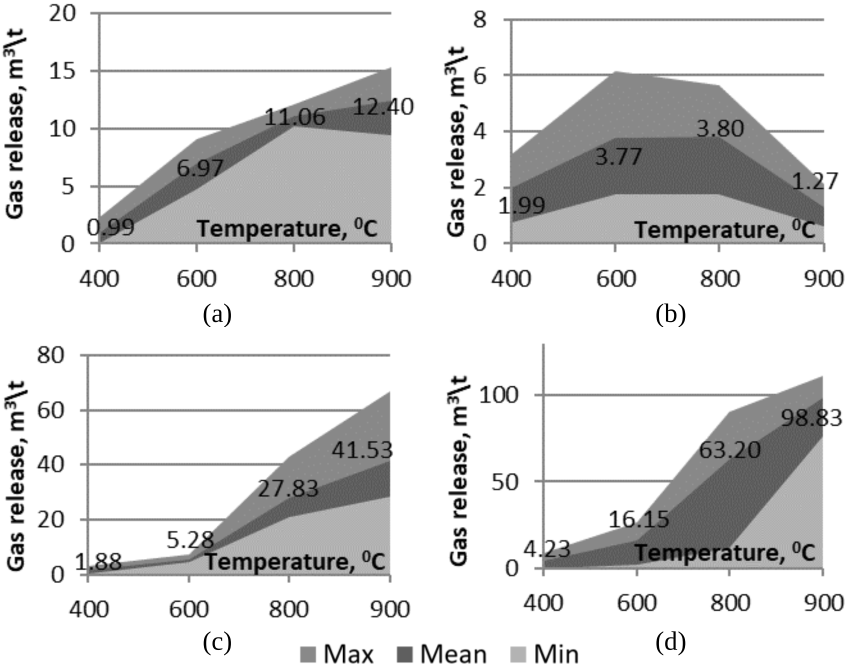

Fig. 1. Content dependence of carbon dioxide CO_2 (a), oxygen O_2 (b), carbon monoxide CO (c) and hydrogen H_2 (d) on processing temperature

According to Fig. 1(c) release of CO grows in the range from 1.88 to 41.53 m^3/t with increasing temperature. At the same time, the maximum value of CO was observed at a temperature of 900°C. Carbon monoxide can also affect pipe corrosion, especially when it has high contact with the metal surface of pipes. Also it can react with oxygen in the air and form carbon dioxide. Carbon dioxide can contribute to corrosion reactions on the metal surface, which was already mentioned above. In the presence of moisture, carbon monoxide can form a carbon dioxide solution that can react with the metal surface and promote corrosion. This gas can promote hydrogen corrosion, where hydrogen interacts with the metal structure, can penetrate it and cause the material to lose strength.

According to Fig. 1(d) release of H_2 grows in the range 4.23 to 98.83 m^3/t with increasing temperature. At the same time, the maximum value of gas release was observed at a temperature of 900°C. It is common knowledge that hydrogen can affect the corrosion of the pipes along which it is transported, especially if it is present in an aqueous solution or in water vapor. Hydrogen can penetrate the metal structure and lead to the process of hydrogen fading, where hydrogen dissolves in the metal and can change its structure. This can reduce the strength of the metal and cause it to deform and break. Also, hydrogen can concentrate in defects in the metal structure, such as cracks or micropores. This can lead to rapid propagation of cracks and destruction of the material. Hydrogen can interact with metal, which can contribute to the peeling of corrosion layers and affect the corrosion process. Hydrogen can destroy protective films and coatings on the metal surface, which allows further contact of the metal with aggressive media.

Conclusions. As a result, a quantitative and qualitative assessment of the gas phase formed under action of thermal processing of solid carbon-contained raw materials was obtained. It has been proven that under action of thermal impact on coal sludge samples, gas mixture releases, which includes the following corrosive components: carbon dioxide, oxygen, carbon monoxide and hydrogen. It was found that with temperature increasing, the methane amount rises, reaches a maximum and then decreases, and the amount of hydrogen and carbon monoxide also increases. The percentage of other gases remains practically unchanged. Depending on the choice of a specific process gas in the thermal processing of solid carbon-contained raw materials, it is possible to establish optimal conditions under which other corrosive gases will cause the least impact on the mechanical properties of metal equipment.

1. *Kurta S.A.* Basics of petrochemistry. Tutorial. – Ivano-Frankivsk: Prykarpattia National University named after Vasyl Stefanyk, 2020. – 193 p. (in Ukrainian).
2. *Sergeyev P. V.* Selective flocculation of coal slurries with organic reagents: [monograph]. – Donetsk: Eastern publishing house, 2010. – 240 p. (in Ukrainian)
3. *Agaiev R., Vlasenko V. and Kliuiev E.* Methane receiving from coal and technogenic deposits // Progressive Technologies of Coal, Coalbed Methane, and Ores Mining. – Netherlands: CRC Press/Balkema, 2014. – p. 113–120.
4. *Ahaiev R.A., Kliuiev E.S. and Sapunova I.O.* Determination of quality parameters of solid carbon-contained raw material in laboratory conditions for its thermal processing // Collection of scientific works of NSU / State higher educational institution "National Mining University". – Dnipro, 2018. – №. 54. – p. 197–205. (in Ukrainian