Conference Paper

Plate Heat-exchangers in Modern Waste Heat Recovery Systems of Hot Blast Stoves and Other Metallurgical Equipment

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Abstract

One of the main factors which defines modern economy is energy efficiency, namely, rationality of use of natural resources, first of all fuel resources, their economic use. Energy saving and energy efficiency improvement should be considered as one of the main sources of future economic growth.

Keywords: heat recovery system, economic and ecological effect, plate heat-exchangers, ribbed panel, laser welding, ribbed panels, heating unit

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1. Introduction

Heat recovery in the waste heat recovery system (WHRS) allows saving up to 30–40% of consumed energy. Moreover, the use of pre-heated air instead of the air with the ambient temperature improves fuel combustion in a furnace, reduces its chemical and mechanical properties of unburned carbon. As a result, with the same fuel consumption the amount of heat received in the combustion process increases by 10–15% [1–4].

Apart from the economic benefit from implementation of the heat recovery system there is an ecological effect. This is reduction of waste gas heat emission into the atmosphere due to significant reduction of the waste gas temperature in waste heat recovery systems.

The following factors of WHRS implementation shall be taken into account:

1. The payback period can be in the range from several months to five–ten years depending on many parameters including WHRS dimensions, waste gas temperature, economic effect, etc.

2. Availability of the required area for installation of the equipment.

3. The usage of waste gas heat can be limited owing to the difference between gas temperature and demand for the certain temperature in the inlet of the energy consuming equipment. The acceptable value of the indicated difference is determined by the balance between energy saving and expenses for reconstruction of the equipment which will use this heat.

Taking a decision of additional investment, a period of engineering and construction of a new WHRS should be taken into consideration.

2. Content

The waste heat recovery system consists of equipment complex. They are, first of all, heat-exchangers, shut-off and control valves, waste gas, air or gas pipelines, and a control system.

A key to success in implementing WHRS is a right choice of the main equipment, that is, heat-exchangers.

Lately, with development of high-frequency welding and laser welding technologies plate ribbed heat-exchangers have become widespread especially for WHRS with high temperatures of waste gases (400–1000°C).

Plate heat-exchangers have a long history. Back in 30s of the last century plate heat-exchangers with units consisting of a set of thin-walled flat sheets were widely spread. The necessary heat-transfer surface is provided due to a large number of these sheets, at the same time either this equipment shall have a large volume or gaps between the plates shall be quite small.

Pursuit to increase the heat-transfer surface due to small gaps with many plates resulted in significant growth of aerodynamic resistance of heat-exchangers. Significant aerodynamic resistance excludes possibility of heat exchange of large volume of gases (only if quite sizable equipment is not used which is not always possible). Pushing large volume of gases through the equipment with high resistance by means of powerful fans leads to 'coalescence' of plates and destruction of heat-exchangers.

Replacement of flat plates with corrugated or wavy plates of different configuration does not lead to significant increase of surface but even increases aerodynamic resistance more. When operating corrugated heat-exchangers with high temperature of waste gases, a substantial problem was detected: plates crack within a short period of operation and, as a consequence, heat-exchangers break down. This phenomenon happens especially quickly (from 4 months to one year) at high temperature fluctuations within a short time.

The survey of the failed heat-exchangers showed as follows: cracking occurs due to ‘mechanical’ corrosion, that is, stresses in metal lead to quick metal fatigue. This conclusion was made based on investigations of metal cross-section in the places of plate cracking [5]. ‘Mechanical’ corrosion of plate heat-exchangers is connected, in the first place, with plate manufacturing technology, that is, when plate is stamped, intercrystalline bonds are damaged in the metal structure and plate microvibration occurs in the course of operation of plate heat-exchangers which results in their cracking within a short period of their operation.

Development of new welding technologies gave a new incentive to development of plate heat-exchangers. As a result of modernization of welding equipment and laser welding technology [6], it became possible to manufacture ribbed panels of rolled steel sheet (1.0–1.5 mm) with T-butt welding of ribs to the basic sheet (Figure 1).

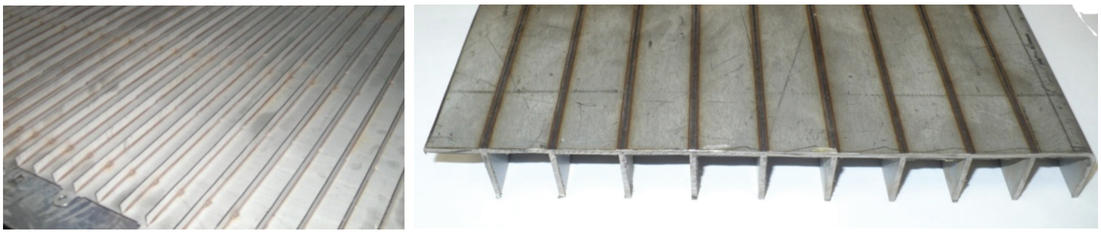

Figure 1: Ribbed sheet panel manufactured by laser welding.

A ribbed panel is an active heat-exchange surface. To receive optimum performance of the heat-exchanger it is possible to change panel parameters (height, quantity of ribs, cell dimension) over a wide range. A panel 1 m^2 in area considering the surface with welded ribs can have a heat transfer surface equal to 2–10 m^2 which is many times more than heat transfer surface of tube heat exchangers.

To receive ribbed panels of such design by known industrial methods is near-impossible. It explains the absence of reliable plate heat-exchangers nowadays especially in sphere of high temperature heat exchange.

Thanks to special features of laser welding the seam does not differ from the base metal, it is full-strength, flexible, permits bends and local deformation, not prone to corrosion (including intercrystalline corrosion). The method developed by KALUGIN company enables manufacturing panels of corrosion-resisting (as well heat-resistant) steel and alloys with the operating temperature up to 1100–1250°C. It is also possible to manufacture bimetal welded joints (for example, a plate is made of one steel and ribs is of other steel or alloy) and heat-exchangers made of high-temperature metal from a high-temperature side and of ordinary stainless or low-carbon steel from a low-temperature side. These possibilities can be rather useful considering high prices of stainless and especially heat-resistant steel. New heating units of heat-exchangers are produced by combining ribbed panels. Their design is quite simple (Figure 2). The unit presents 'a layer cake' made of alternate cavities of heating and heated medium. To provide the required capacity of the heat-exchanger, a unit with necessary number of ribbed plates is assembled and heat-exchanger arrangement is selected (Figure 3). Diffusors and confusors are installed in the inlet and outlet of the gas mains.

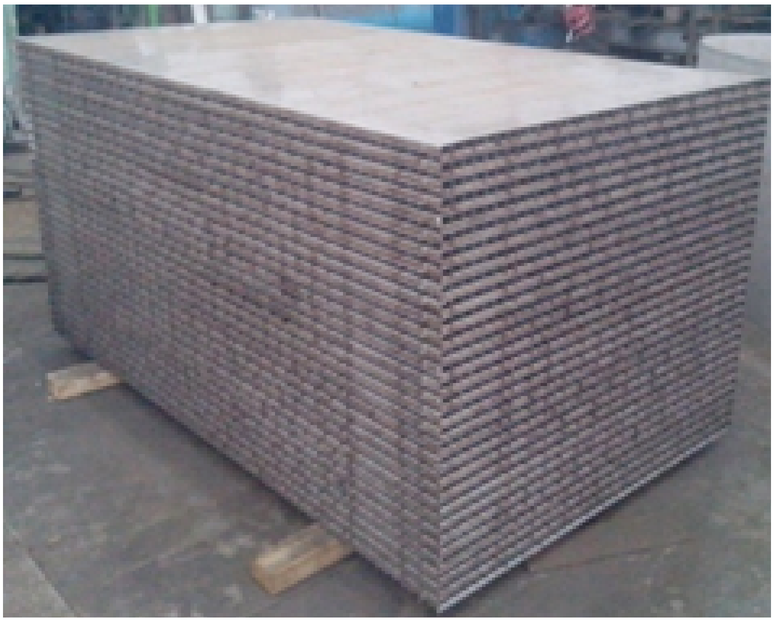

Figure 2: Heat-exchanger heating unit.

Thermal expansion joints are installed between heating units, in the inlet or outlet of heating or heated main.

Different combination of arrangement of panels and heating units relative to each other allows creating one-pass and multipass heat-exchangers.

Unit arrangement makes it possible to simplify erection, maintenance and repair of heat-exchangers. Open access to channels of gas mains allows inspecting and cleaning the channels and relatively low aerodynamic resistance permits high speed of gas flow (over 14 m/s) which allows to avoid dust deposit (clogging) in channels which worsens parameters of heat-exchangers.

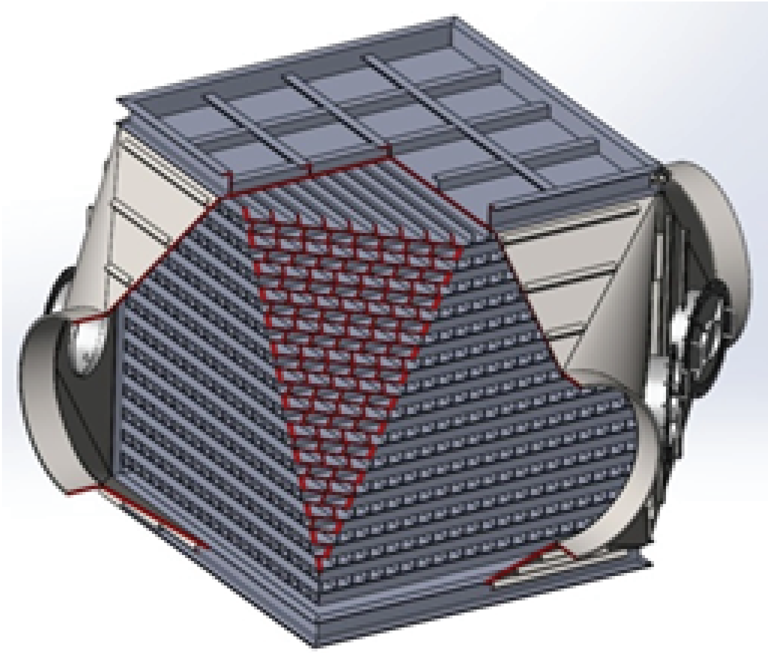

Figure 3: Plate heat-exchanger.

3. Summary

Studies showed that due to small element thickness new heat-exchangers have additional merits: quick response, thermal plasticity which is especially important while operating on waste gases at unstable temperature, for example waste gases from shaft furnaces and cupola furnace with large operating temperature spread (200–1000°C) within a short period of time.

References

[1] Shklyar, F. R., Malkin, V. M., Kashtanova, S. P., et al. (1982). *Hot Blast Stoves (Designs, Theory, Operating Conditions)*, p. 176. Moscow: Metallurgy.

[2] Gres, L. P. (2004). Vysokoeffektivnyi nagrev domennogo dut'ia, p. 491, Monograph. Ukraine, Dnepropetrovsk Porogi.

[3] Aksyushin, M., Kalugin, M., Malikov, G., et al. (2018). Improvement of the energy efficiency of hot blast stove performance. Advanced Methods and Technologies in Metallurgy in Russia (Innovation and Discovery in Russian Science and Engineering), pp. 169–176. Springer.

[4] Schulz, L. A. (2014). *Energy-ecological Analysis of Metallurgical Processes Efficiency*, p. 267. MISiS Publishing House.

[5] Burlov, V. V. (14–17 February 2013). Design features of plate heat-exchangers which influence on their operation in oil refining, Council of chief mechanics of oil-refining and petrochemical enterprises of Russia and CIF countries. Retrieved from http://www.lotus1.ru/company_news/0/211?p=13

[6] Murzin, Yu. A., Aksyushin, M. E., and Bogdanov, K. O. Sheet Panel with Ribs and Its Manufacturing Method, RU 2567971, Invention Patent Specification.