Conference Name: STRA International Conference on Engineering & Technology, 07-08 October 2025, Istanbul
Conference Dates: 07-Oct- 2025 to 08-Oct- 2025
Conference Venue: Nippon Hotel, Taksim, Istanbul, Turkey
Appears in: MATTER: International Journal of Science and Technology (ISSN 2454-5880)
Publication year: 2025

Gunec et. al, 2025

Volume 2025, pp. 101-110

DOI- https://doi.org/10.20319/stra.2025.101110

This paper can be cited as: Gunec, A., Rigan, M., Mendi, E., Osman Aydinnari, A. & Ozal S.(2025). Efficiency Enhancement in the Recuperator of a Reheating Furnace. STRA International Conference on Engineering & Technology, 07-08 October 2025, Istanbul. Proceedings of Scientific and Technical Research Association (STRA), 2025, 101-110

EFFICIENCY ENHANCEMENT IN THE RECUPERATOR OF A REHEATING FURNACE

Alper Güneç
R&D Center, Tosyalı Holding, Osmaniye, Turkey
alper.gunec@toscelik.com.tr
Meliha Rigan
R&D Center, Tosyalı Holding, Osmaniye, Turkey
alper.gunec@toscelik.com.tr
Elif Mendi
R&D Center, Tosyalı Holding, Osmaniye, Turkey
alper.gunec@toscelik.com.tr
Ali Osman Aydınnarı
R&D Center, Tosyalı Holding, Osmaniye, Turkey
alper.gunec@toscelik.com.tr
Sena Ozal
R&D Center, Tosyalı Holding, Osmaniye, Turkey
alper.gunec@toscelik.com.tr

Abstract

In today's world, increasing environmental concerns have intensified the focus on renewable energy sources and effective energy management practices. In industrial processes, particularly in areas with high energy consumption, waste heat recovery has become one of the primary research topics. Reheating furnaces used in the steel industry reach extremely high temperatures during rolling operations, with approximately 50–70% of this energy being released directly into the atmosphere through flue gases. In this context, flue gases stand out as one of the most significant sources of waste heat. The aim of this study is to recover the waste energy contained in the flue gases emitted to the atmosphere from a slab reheating furnace used in the hot rolling *process of the iron and steel industry by means of a recuperator. Through the newly implemented recuperator replacement, 31,274.93 kW of energy recovery was achieved and 6.32 tons of carbon emissions were reduced. Consequently, the amount of energy released into the atmosphere was decreased, and a significant reduction in natural gas consumption of the furnace was obtained.*

Keywords:
Waste Heat Recovery, Recuperator, Energy Efficiency, Emission Reduction, Steel Industry, Reheating Furnace

1. INTRODUCTION

In recent years, the rising trend of fuel prices and growing concerns regarding global warming have driven efforts to reduce greenhouse gas emissions in industry and to enhance plant efficiency. Industrial waste heat is defined as the energy released during processes that remains unused and is discharged into the environment. Waste heat recovery can be implemented through various technologies in order to provide valuable energy resources and reduce overall energy consumption. Therefore, the integration of waste heat recovery systems into industrial processes has become an important research area in terms of reducing fuel consumption, mitigating harmful emissions, and improving production efficiency [1].

The steel industry, being one of the most energy-intensive sectors, places particular importance on waste heat recovery. Waste heat recovery methods aim to capture waste heat generated from a process—either through a gas or a liquid medium—and transfer it back into the system as an additional energy source [2]. The main techniques used for flue gas recovery include recuperators, regenerators, economizers, waste heat boilers, and organic Rankine cycle (ORC) systems.

In the literature, several studies have investigated these techniques. In the work of Manatura and Tangtrakil, the combination of regenerative burners and recuperators was employed to enhance the energy efficiency of reheating furnaces, achieving 43.3% energy savings compared to systems with recuperators alone, and increasing furnace efficiency to 80.1% [3]. Ertem et al. conducted a comprehensive study on heat balance and energy efficiency in industrial reheating furnaces, reporting an energy balance within a 6.7% margin of error, furnace efficiency at 38.3%, and emphasizing that the greatest loss originated from flue gases [4]. In the study by Eyidoğan et al., carried out in a rolling mill reheating furnace, mass and energy balances were established based on measurements of temperature, pressure, velocity, and flue gas composition; furnace efficiency was calculated as 52.8% [5]. Chakravarty et al. reported that, following improvements in a billet reheating furnace, a 14.7% fuel saving was achieved along with an 11.11% increase in billet efficiency [6]. Schwarzmayr et al. investigated a packed bed thermal energy storage (TES) system for storing waste gas heat in the iron and steel industry and demonstrated that, despite the dust load in flue gases, the system could be safely implemented, providing an effective solution for waste heat recovery [7]. Ravindran et al. developed a hybrid system capable of operating as both a high-temperature heat pump (HTHP) and an ORC mode; experimental results showed that this system could convert low-temperature waste heat into both process heat and electricity without dissipation [8].

In the subsequent sections of this paper, the design characteristics and implementation steps of the new recuperator system installed in the reheating furnace are described in detail. Thereafter, field data and energy balance calculations are presented to analyze the effects of the system replacement on furnace performance. Finally, based on the obtained results, the effectiveness of the recuperator application in terms of energy savings and emission reduction is discussed, and overall conclusions are drawn.

2. METHODOLOGY

This study focuses on improvement practices implemented in the existing recuperator system of a reheating furnace, with the objective of enhancing the energy recovery efficiency of waste heat from flue gases. The research methodology consists of three main stages: examining the performance of the current system, identifying the improvement parameters, and comparatively evaluating the energy-saving performance after the improvement.

In the first stage, the recuperator system of the plant was analyzed in detail. Within this scope, flue gas temperatures, air flow rates, preheated air temperatures, and thermal losses in the system were measured to establish a fundamental dataset. Based on the obtained findings, four key improvement areas aimed at increasing system efficiency were identified.

2.1. Improvements Implemented within the Scope of the Project

2.1.1. Enhancement of Recuperator Material Quality

In order to extend the service life of recuperator tubes exposed to high-temperature (approximately 800–1000 °C) corrosive flue gases from the furnace and to improve heat transfer efficiency, the material selection was strategically reconsidered. By adhering to the principle of cost-effectiveness, steels of different grades were selected based on the levels of thermal and chemical stress to which the tubes were subjected. This hybrid material approach not only prolonged the overall service life of the recuperator but also optimized the investment costs.

2.1.2. Insulation of the Recuperator Chamber with Refractory Material

To minimize heat losses occurring in the flue channel section, the outer surface of the recuperator chamber was reconstructed with high-temperature-resistant refractory bricks, as shown in Figure 1. This application reduced heat dissipation from the channel walls to the environment, thereby allowing the thermal energy in the flue gases to be more effectively transferred to the airflow within the recuperator.

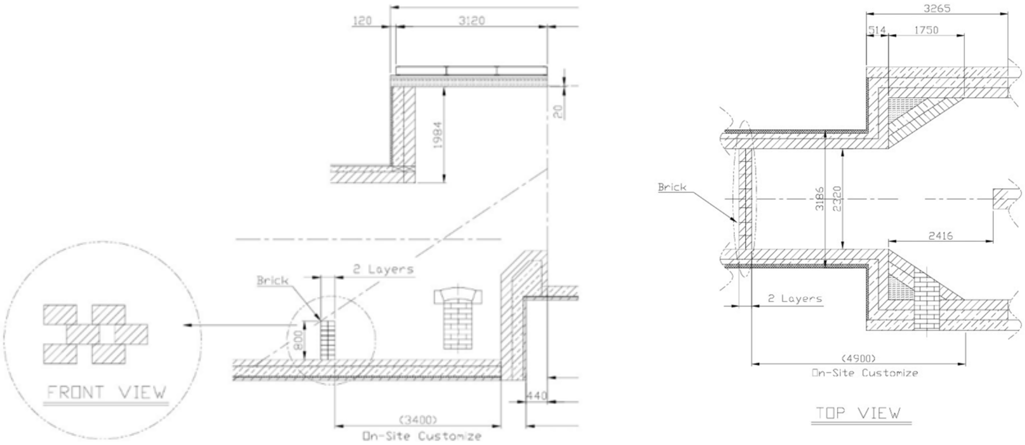

Figure 1. *Flue Channel after Refractory Lining*

2.1.3. Increasing the Heat Transfer Surface Area

To increase the temperature of the preheated air, the total heat transfer surface area was doubled by implementing a dual-recuperator configuration. As shown in Figure 2, the flue gas stream was directed through two recuperator units connected in series. In this way, instead of single- stage heating, a two-stage heating process was achieved, resulting in a higher and more uniform outlet air temperature.

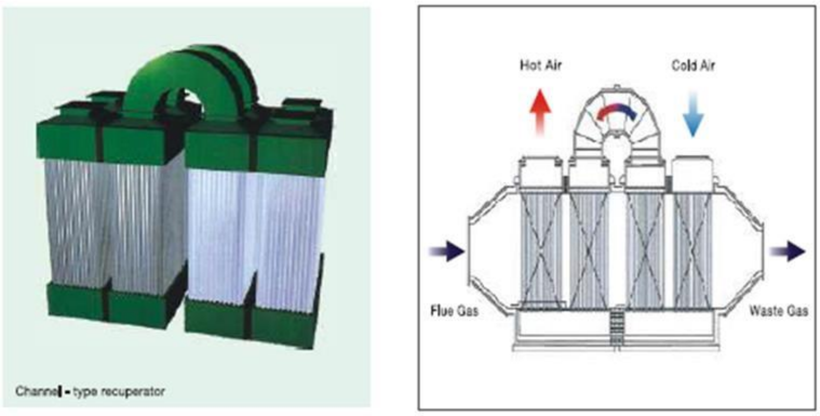

Figure 2. *Dual-Channel Recuperator*

2.1.4. Optimization of Flow Channel Design

To reduce the high-pressure loss and irregular heat transfer caused by turbulence in the flue gas flow of the existing system, the aerodynamic design of the recuperator channel was improved. As shown in Figure 3, sharp corners and sudden cross-sectional changes were minimized, resulting in a flow profile closer to laminar conditions with lower pressure losses. This modification not only reduced fan energy consumption but also provided more uniform heat transfer across the heat exchanger surface.

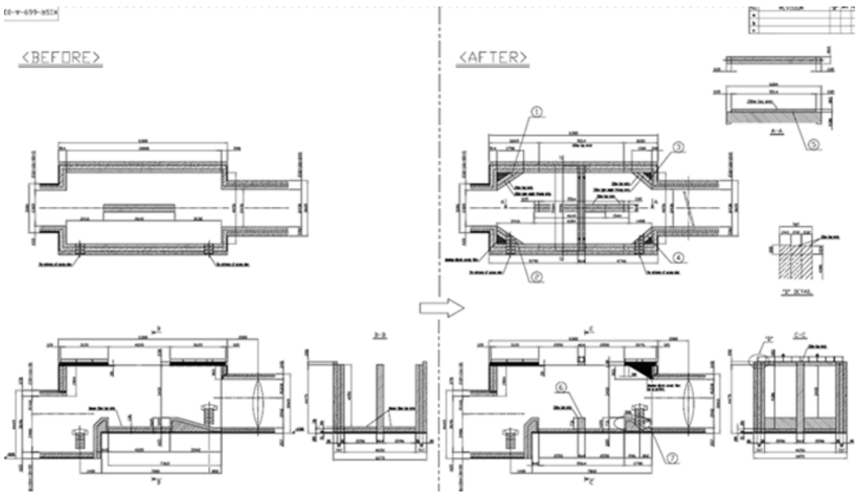

Figure 3. *Flue Channel Before and After Optimization*

3. FINDINGS

In this study, the recuperator system was examined in detail and a comprehensive analysis was carried out. Following the improvement practices, the hourly natural gas consumption of the reheating furnace and the tonnage of the heat-treated material were measured, and the specific natural gas consumption per unit product was calculated. As a result of the improvements, material quality was enhanced and the service life of the recuperator material was extended. After the implementation of three different improvement measures, an increase in performance and a reduction in natural gas consumption were observed. The natural gas consumption values and production rates of the reheating furnace prior to the improvements are also presented. The natural gas consumption values before and after the project, along with the amount of energy recovered upon completion of the project, are illustrated in Figure 4.

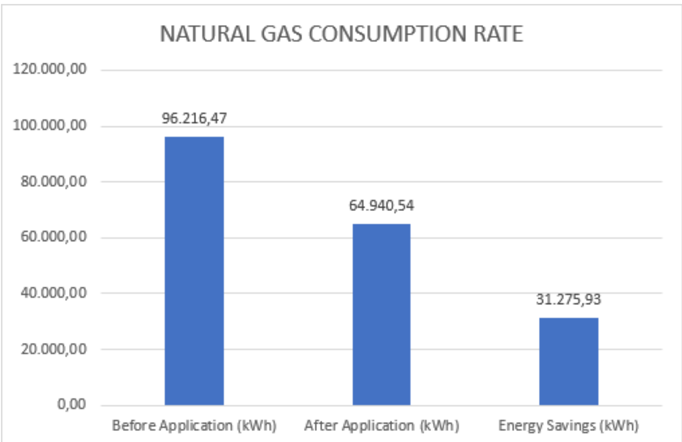

Figure 4. *Natural Gas Consumption and Energy Ratios*

In this study, the calculation of natural gas consumption was based on natural gas with a lower heating value of 8,250 kcal/Sm³. To determine the amount of natural gas savings, Equation (1) was applied. Within the scope of this equation, the parameters considered included the annual energy gain of the component (A), annual operating time (B), the measured power before the implementation (C), and the total measured power after the implementation (D).

$$A = B \times C - D \qquad (1)$$

This equation demonstrates the energy gain obtained by multiplying the difference between the measured power values before and after the implementation with the annual operating time.

As mentioned in the methodology section, the insulation of the recuperator chamber with refractory material minimized heat losses. Through the new design, thermal insulation was enhanced, enabling more efficient recovery and utilization of waste heat. The reduction of heat losses in the flue section prevented thermal dissipation to the environment and improved the effectiveness of the airflow. Consequently, the efficiency of the reheating furnace increased, energy consumption decreased, and overall system performance was enhanced. In addition, a significant reduction in energy consumption per unit of production was observed.

The planned and actual measurements of efficiency components before the implementation are presented in the table below. The difference between the projected values prior to the project and the realized values after the project completion is illustrated in Figure 5.

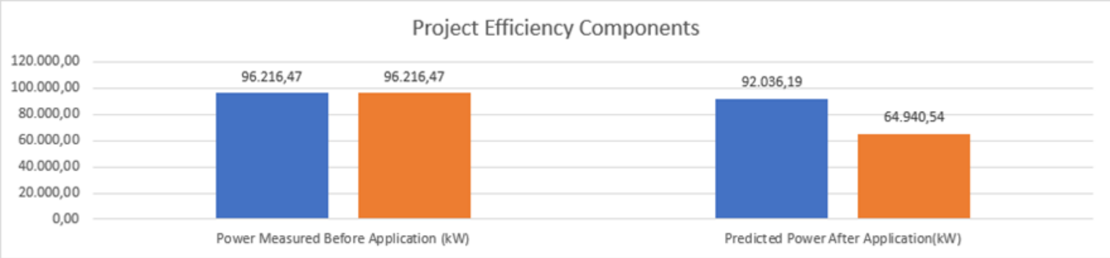

Figure 5. *Project Efficiency Components Before and After Implementation*

Another significant outcome of the project was the emission reduction. As a result of the project, natural gas consumption was reduced by 31,274.93 kW, leading to a decrease in the amount of gases and waste materials released into the environment. Moreover, the implemented improvements ensured compliance with legal regulations and international standards, while achieving a noticeable reduction in the plant's carbon footprint. The emission reduction was calculated using Equation (2).

$$CO_2\ Emission\ (kg) = Energy\ (kWh) \times Emission\ Factor\ (kg/kWh) \quad (2)$$

The achieved emission reduction corresponds to **6.32 tons of CO_2**.

4. DISCUSSION

Prior to the implementation, the flue gas line of the reheating furnace was directed from two separate branches into a single stack, with a total of eight recuperators installed on these two flue gas channels. Due to their low heat recovery efficiency and the deformations that occurred during operation, the old-type recuperators were dismantled. Instead, a total of eight high- efficiency next-generation recuperators were integrated into both flue gas lines, thereby enhancing heat recovery. According to the measurements taken within the scope of the project, the hourly energy consumption of the reheating furnace before the implementation was 96,216.47 kWh. After the implementation, the measurements revealed a 32.5% reduction in hourly energy consumption, amounting to 64,940.54 kWh. With the application of the project, more heat was recovered from the flue gas, resulting in a higher preheating of the combustion air supplied to the furnace. Consequently, the amount of energy released into the atmosphere was reduced, and the natural gas consumption of the furnace decreased. In addition, reductions in electricity consumption contributed to a decrease in the carbon footprint, supporting the achievement of green transformation in industry. The success obtained indicates that, if widely implemented, such applications have the potential to contribute positively to efforts aimed at reducing the industrial-scale use of fossil fuels and lowering carbon emissions.

5. CONCLUSION

This study aimed to enhance the energy efficiency of the recuperator system in a reheating furnace. As a result of detailed measurements, analyses, and implementations conducted throughout the study, reductions of 31,274.93 kW in energy consumption, 6.32 tons in carbon emissions, and notable process improvements were achieved. The thermal efficiency of the existing recuperator system was improved, leading to a 32.5% reduction in fuel consumption. This reduction contributed both to lowering production costs and to decreasing the plant's overall energy demand. Through more effective heat recovery, the reduction in natural gas consumption resulted in a measurable decrease in greenhouse gas emissions, positively supporting the company's sustainability objectives and compliance with environmental regulations. The technical revisions carried out in the recuperator system also ensured a balanced temperature distribution within the furnace and enabled the process to operate at optimal conditions. Consequently, the service life of the recuperators was extended, and maintenance requirements were reduced. These outcomes can serve as a model for similar industrial applications.

The findings demonstrate that systematically addressing heat recovery in high-temperature industrial furnaces provides significant benefits from both economic and environmental perspectives. This study makes a concrete contribution to energy efficiency policies in the iron and steel industry and offers a guiding example for future projects of similar nature.

References

A cold model study on powder hold-up and pressure drop. Journal of Energy Storage, 75, 109735.
https://doi.org/10.1016/j.est.2023.109735

Chakravarty, K., Mondal, S., & Kundu, R. (2024). Improving the energy efficiency in a walking hearth type reheating furnace by energy balance method and optimizing the resources.
https://doi.org/10.1016/j.meanee.2024.100010

Ertem, G., Çelik, B., & Yeşilyurt, S. (t.y.). Endüstriyel tav fırınlarında ısı denkligi hesaplamaları ve enerji verimliliğinin belirlenmesi. IV. Ege Enerji Sempozyumu, İzmir

Eyidoğan, M., Kaya, D., Dursun, Ş., & Taylan, O. (2014). Endüstriyel tav fırınlarında enerji tasarrufu ve emisyon azaltım fırsatları. Gazi Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi, 29(4), 735–743.

Jouhara, H., Khordehgah, N., Almahmoud, S., Delpech, B., Chauhan, A., & Tassou, S. A. (2018). Waste heat recovery technologies and applications. Thermal Science and Engineering Progress, 6, 268–289.
https://doi.org/10.1016/j.tsep.2018.04.017

Manatura, K., & Tangtrakul, M. (2010). A study of specific energy consumption in reheating furnace using regenerative burners combined with recuperator. Kasetsart Journal of Natural Science, 44(5), 1005–1014.

Measurement: Energy, 3, 100010.

Ravindran, R. V., Hewitt, N., Huang, M. J., Cotter, D., & Wilson, C. (2024). *Experimental investigation of a small-scale reversible high-temperature heat pump − organic Rankine cycle system for industrial waste heat recovery*. *Applied Thermal Engineering*, *257*(Part A), 1-15.
https://doi.org/10.1016/j.applthermaleng.2024.124237

Reddy, C. C. S., Naidu, S. V., & Rangaiah, G. P. (2013). Waste heat recovery methods and technologies. Chemical Engineering. *120*(1), 28–38.

Schwarzmayr, P., Birkelbach, F., Walter, H., Javernik, F., Schwaiger, M., & Hofmann, R. (2023). Packed bed thermal energy storage for waste heat recovery in the iron and steel industry: