High velocity burners with finned recuperator for highest efficiency

by Roland Rakette, Dirk Mäder, Birgit Neumann

In the field of process heat utilization, various measures are available for increasing energy efficiency. According to the technological process, a large part of the process heat is generated as waste heat. It is a very effective way of recycling this waste heat directly to the process, e.g. by means of intensive combustion air preheating at industrial burners. The long proven recuperator burners are limited in energy efficiency due to the restriction of the recuperator surface. The use of metal foam in connection with the robust finned tube design generates higher efficiencies which achieve 10–15% energy savings compared to conventional finned tube recuperator burners.

Metal foam has got special properties making it attractive also for burner construction in many respects. This material is mechanically very stable at low mass vs. volume ratio. The mass of metal foam reduces to approx. 10–20% as compared to solid material, depending on type and structure. In open structure, the foam can be well flowed by gases and liquids. The flow conditions can be affected, for instance, by different pore sizes and web thicknesses. Open-pored metal foams consist of a three-dimensional network of pores linked one with another, featuring excellent flow capacity and a very large surface. Specific strength and rigidity as well as energy-absorption capability are much higher than, for instance, that of solid material.

Both the good thermal conductivity of metal foam and the considerable surface enlargement constitute another advantage of this material. When comparing the surface of a cube having a volume of 1 l with that of a body equal in volume made of open-pored metal foam, the external surface of foam increases by 15 to 20 times as a function of the pore size used. Thanks to the use of appropriate temperature-resistant materials, metal foam can also be used for higher temperatures as prevailing on burners. Metal foams can plastically deform unlike brittle ceramic foams and can be handled easier and better when being used.

Based on the recuperated burners already used in many applications which are also equipped with finned-tube recuperators, our work was focused on the clear objective to considerably improve the efficiency of such burners. This can be achieved thanks to the use of metal foam. The newly developed recuperator burner of the type Etamat principally has got the same sub-assemblies, including basic burner as shown in [1].

Thanks to the reconfiguration of the finned-tube recuperator using metal foam, the efficiency of heat transmission, in particular, by improved heat transfer and larger heat transmission surface is even considerably higher in the first step. The use of open-pored foam structures on

Fig. 1: Etamat RHGBS 25 recuperator burner
heat-transmitting surfaces implies that the boundary layer is impaired as well as heat transmission is intensified by considerable eddy formation.

A specially designed burner housing, comprised of the following two parts,

- housing with combustion-air connection, and
- housing with waste gas connection,

provides other heat transmission surfaces between waste gas and combustion air thus ensuring increased heat recuperation from waste gas.

Simple and sturdy construction without filigree and, thus, high-wear and high-maintenance components as well as the compact design are characteristic features of the improved recuperator burner as well as the possibility to feed-in separate cooling air through the central burner tube. Ignition of burner takes place electrically with direct flame monitoring in 1-electrode operation over the whole field of application, thus offering utmost safety in all operating states. Fig. 1 shows the burner with metal-foam recuperator with a nominal power of 25 kW.

Thanks to the entirety of measures taken to improve efficiency of the burner, a firing efficiency is achieved which can be compared to that of regenerative burners of minor capacity. At a waste-gas inlet temperature on recuperator of 1,000 °C, for instance, a firing efficiency defined by the waste-gas outlet temperature of up to 90 % can be achieved as a function of the connected burner load respectively adjusted. The connection flow pressure rates for fuel gas and combustion air will rise due to the increased pressure losses by the foam as compared to the standard finned-tube recuperator and are restricted to 100 mbar. The variations ensured by the foam make it possible to affect the pressure loss via recuperator whereby, however, heat transmission and, thus, efficiency may also vary.

If the achievable fuel-gas saving $E$ is calculated from the combustion efficiency $\eta_{F,new}$ of the Etamat burner and that of the comparative burner $\eta_{F,old}$ using the formula

$$E = \frac{\eta_{F,old} - \eta_{F,new}}{\eta_{F,new}} \times 100\%$$

**Fig. 2:** Fuel saving on Etamat RHGBS recuperator burners and RHGB standard finned-tube recuperated burners as compared to cold-air burners

**Fig. 3:** Etamat burners on a continuous-belt furnace
a saving of up to 50% as compared to conventional cold-air burners and/or 10–15% as compared to finned-tube recuperator burners can be achieved at a maximum operating temperature on burner recuperator of 1,050 °C (Fig. 2).

Because of the higher efficiency of the burner, it is possible to substitute recuperator burners identical in construction showing a higher connected burner load. For instance, a finned-tube recuperator burner of approx. 39 kW can be substituted with an Etamat burner of approx. 35 kW connected load.

The burners are preferably used for indirect heating in jacket radiant tube of 200 mm in diameter. Due to the partially small pore sizes of foam, clean waste gas is required to preclude that particle sediments will cause a rise of pressure loss via the recuperator and, as a consequence thereof, the burner capacity decreases at equal connection pressure rates of media being available. The same applies to combustion air. As to indirect heating, these prerequisites are normally provided for the burners.

Further to the use of the complete burner on new installations or the complete substitution of an old burner, it is possible to subsequently increase the efficiency of existent burners identical in construction with finned-tube recuperator only by replacement of the recuperator itself while maintaining the other components (rebuild variant). Energy saving as compared to finned-tube recuperator burners will amount here to a maximum of 10%.

Table 1: Technical data of Etamat burners on continuous-belt furnace

<table>
<thead>
<tr>
<th>Etamat burner</th>
<th>RHGBS (U) (rebuild variant)</th>
<th>RHGBS 25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connected load kW</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Gas connection pressure mbar</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>Air connection pressure mbar</td>
<td>78</td>
<td>78</td>
</tr>
<tr>
<td>Recuperator inlet temperature °C</td>
<td>1,000</td>
<td>1,000</td>
</tr>
<tr>
<td>Combustion efficiency</td>
<td>0.86</td>
<td>0.90</td>
</tr>
<tr>
<td>Waste-gas temperature °C</td>
<td>&lt; 340</td>
<td>&lt; 250</td>
</tr>
</tbody>
</table>

Both designs of Etamat burners have successfully been in use on a continuous-belt furnace of Messrs. EJOT GmbH & Co. KG in Tambach-Dietharz, Germany, since November 2015 (Fig. 3). The burners function exceedingly satisfactorily whereby, further to the higher energy efficiency, the small number of burner faults becomes positively obvious at an average of approx. 20,000 burner startups per month. The technical data determined from measured values of burners on the installation is listed up as average values in Table 1. Emission measurements taken under operating conditions show average values for NO, which do not exceed the mass per unit volume of 0.35 g/m³ (nitrogen monoxide and nitrogen dioxide, indicated as nitrogen dioxide) according to the Technical Instruction on Air Quality

Fig. 4: Sound pressure level for selected recuperator burners with indirect heating
The CO emissions are practically close to 0 ppm.

The good damping properties of foam already mentioned are also useful with regard to acoustic aspects to reduce the sound pressure level.

Usually, the A-weighted sound pressure level $L$ is specified to describe the sound impacts on a particular place to characterize a burner. As to the point-related sound pressure level measurement, measured values are determined at a distance of 1 m from the burner along its axis. Further to the value obtained during burner operation, the sound pressure level with shut-down burner is also determined (background value). Therefrom, the burner values can be assessed as follows:

Burner value ($B$) = measured value including background value ($G$) – background value ($H$)

$$L_B = 10 \times \log(10^{0.1 \times L_G} - 10^{0.1 \times L_H})$$

Among others, the assessment does not consider the reflection and/or absorption behaviour of space around the furnace used for measurements.

Standard recuperator burners show an approximate sound pressure level within a range from 70–75 dB(A) for indirect heating. An enormous decrease of sound pressure level can be achieved when using the metal foam recuperator. As shown in Fig. 4, sound pressure level values of under 60 dB(A) can be achieved depending on the foam coat. For better illustration, it can be specified that any increase of level by 10 dB is perceived by the human auditory sense as approximate doubling of loudness.

**CONCLUSION**

To increase efficiency of industrial gas burners has been the subject matter of many efforts for a long time. Intensive preheating of combustion air is an essential focus in this respect. Even on energy-efficient recuperator burners, the use of metal foam offers a potential for further improvement of heat transmission and, thus, for further increase of efficiency. In terms of the further development of proven finned-tube recuperator burners, efficiency levels can be achieved which almost comply with the values obtained on regenerative burners. Moreover, the use of foam materials ensures an excellent sound absorption by means of which the sound pressure level on burners can be decreased considerably as demonstrated on the basis of the recuperator burner described herein.

**LITERATURE**


**AUTHORS**

Dr.-Ing. Roland Rakette  
NOXMAT GmbH  
Oederan, Germany  
Tel.: +49 (0)37292 / 6503-60  
drrakette@noxmat.de

Dipl.-Ing. (FH) Dirk Mäder  
NOXMAT GmbH  
Hagen, Germany  
Tel.: +49 (0)2334 / 4423-58  
maeder@noxmat.de

Birgit Neumann  
EJOT GmbH Co. KG  
Tambach-Dietharz, Germany  
Tel.: +49 (0)3625 / 242-177  
bneumann@ejot.de