Application of Flameless Oxidation in Glass Melting Furnaces GlassFLOX™

Dr.-Ing. Anne Giese, Dipl.-Ing. Uwe Konold,
Dr.-Ing. habil. Ahmad Al-Halbouni, Prof. Dr.-Ing. habil. Klaus Görner
Gaswärme-Institut e. V. Essen

Gottfried Schwarz, Benjamin Köster
Hotwork International GmbH, Partenstein

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Gaswärme-Institut e. V.
Essen

Gaswärme-Institut e. V. Essen (GWI)
Hafenstraße 101
45356 Essen
Tel.: +49 (0)201 3618-0
Fax: +49 (0)201 3618-102
www.gwi-essen.de

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Dr.-Ing. Anne Giese, Dipl.-Ing. Uwe Konold, Dr.-Ing. habil. A. Al-Halbouni, Prof. Dr.-Ing. habil. Klaus Görner
Gaswärme-Institut e.V., Essen, Industrial Gas Utilisation Dept.,
Phone +49 201 3618 257; Fax +49 201 3618 238; a.giese@gwi-essen.de

Gottfried Schwarz and Benjamin Köster,
Hotwork International GmbH, Am Lindenbrunnen 5, 97846 Partenstein;
Phone +49 09355-9728 0; Fax +49 09355-9728 30; contact@hwi-gmbh.de

Abstract

This paper gives an introduction into a finished research project [1] with the abbreviation GlasFLOX®. The project was aimed at a process improvement of a glass melting furnace operated with recuperative air preheating. The improvement was realized with the operation of new burners using the flameless oxidation principle. Due to a more suitable coverage of the glass melting surface a better radiative heat transfer towards the product and an increased efficiency would be realized. In the same time the excellent NO_x reduction properties of the flameless oxidation principle contributed to lower emissions – 50 % NO_x reduction was realized. Based on burner development and testing at GWI high temperature test rig the results of these tests was transferred to a glass melting furnace using computational fluid dynamics (CFD). Detailed measurements before and after the burner exchange has been showed the suitability of the new burners. This contribution describes the background and the carried out work steps as well as the special boundaries conditions which has been considered.

Keywords: Glass melting furnace, NO_x reduction, process improvement, flameless oxidation, increased efficiency, heat transfer improvement

Background of the project

Some decades ago the decrease of NO_x emissions coming from industrial fossil fuel fired processes was declared to be necessary. After this step several techniques [3] were developed in order to reduce the NO_x formation during combustion processes. One of the most successful methods was the flameless oxidation (FLOX® [2]) developed by the WS company, Renningen, Germany. This technique is in operation in several industrial high temperature applications successfully. Although GWI presented the FLOX® principle at several expert group meeting of the German and European glass industry the response was suspicious of an application of FLOX® in their furnaces.

Restrictions regarding glass furnaces

The flames in glass melting furnaces are positioned over the surface of a melting tank, which is fitted with batch, raw melts and refined glass. Furnace and tank are building an unit. Originated by older combustion methods and caused by the need to reach higher melting surface related outputs, luminous flames with a high content of soot radiation are still required in glass industry.
A comparison between the operation of a furnace using heavy fuel oil and diesel leads to the conclusion that due to the higher carbon content of heavy fuel oil a more intense radiation could be reached which results in a 6 % higher output. In the beginning of the utilization of natural gas to heat glass furnaces it was found out that the sharp gas flames came along with production disadvantages due to the lower solid body radiation content of the flames. Since high temperature fuel cracking is applied to natural gas fired glass furnaces it is possible to produce natural gas flames with a higher luminosity which results in production rates comparable to fuel oil combustion.
Regarding to the non luminous – almost invisible – flames the mistrust of glass industry towards FLOX® is understandable. In addition the higher velocities these burners increase the fear of so called carry over. Here the raw materials like sand and soda were blown away from the melting surface directly into the flue gas duct and into the filter.

Project introduction

In spite of the existing restrictions GWI initiated an European research project [4] abbreviated EURONITE to investigate the use of principle of flameless oxidation for glass melting furnaces. Based on successful results achieved in this project GWI convinced OSRAM as a glass producing company and Hotwork International as a burner manufacturer to take part within a follow up research project which was funded by the German Ministry of Economics and Labour (BMWi).

The project targets were the application of the FLOX® technique at an unit melter type glass furnace in order to reduce the energy consumption and to decrease NO_x emissions. In order to minimize the risk of production defects the new FLOX® burners were first tested at the high temperature test plant of GWI. The results were transferred to the OSRAM furnace using computational fluid dynamics (CFD) with validating burner tests.

Results

In a first step the new GlasFLOX® burner has been designed. Special attention has been paid to the velocity at the burner tip and the pressure loss because these values should vary only within certain limits. After this, numerical simulations of the standard burner and the GlasFLOX® burner have been carried out. In this context the comparison of the velocity distribution, the temperature distribution as well as the length of the flame is of particular interest. Figure 1 shows the geometry of both burners. The burners were investigated in detail at GWI high temperature rig. Figure 2 shows the comparison of the CO emission and the temperature distribution of both burners. The measurement of the CO emission distribution showed that the reaction zone of the GlasFLOX® burner is shorter. In addition the temperature peek of the FLOX® burner is about 50 K lower than the maximum temperature of the standard burner. This results in a huge difference in NO_x concentrations. For the standard burner 1183 mg/m³$_N$ related to 8 % excess oxygen in the dry flue gas were measured – whereas for the FLOX® burner only 484 mg/m³$_N$ were detected.

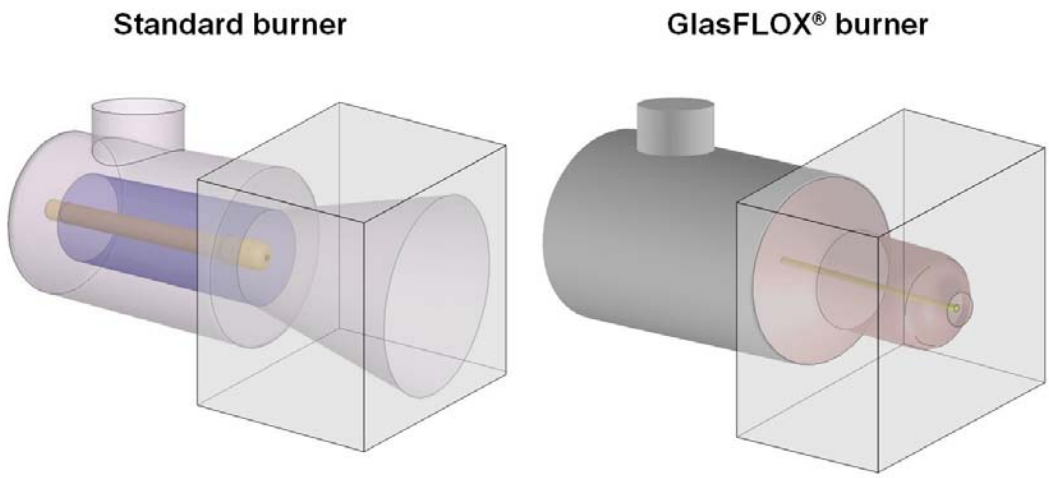

Fig. 1: geometry of standard burner (left) and GlasFLOX® burner (right)

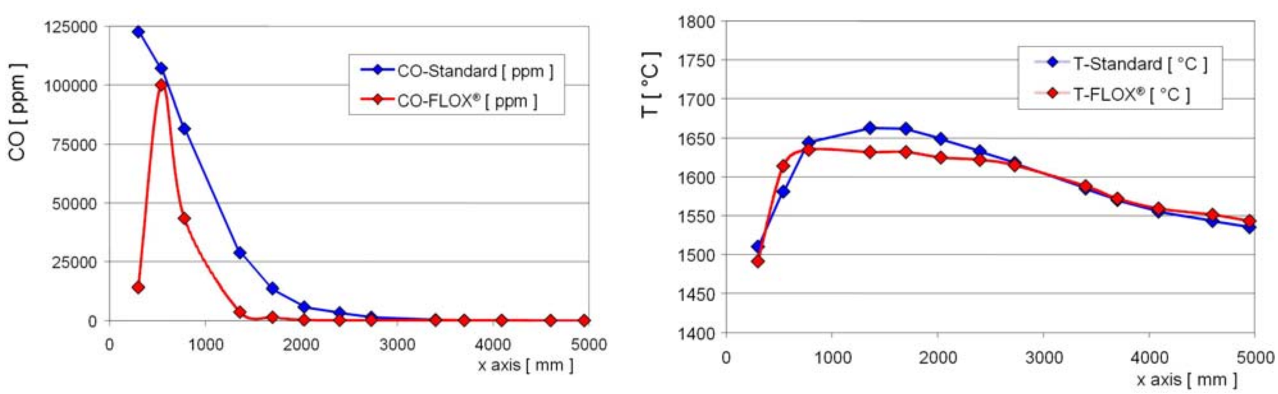

Fig. 2: Measured values of CO emission and temperature on the axis of the test furnace.

Beside the experimental investigations the computational fluid dynamics (CFD) tool FLUENT was used to transfer the results to the OSRAM furnace. In order to avoid the direct impingement of the flames the positions of the burners were of particular interest. Furthermore the numerical simulations depicted an impression of the variation of the flow and temperature fields in the furnace.
In Figure 3 the first step of the rebuilding of the OSRAM furnace is shown. 4 of 10 standard burners were replaced by GlasFLOX® burners. Figure 4 gives an impression of the changing in the velocity distribution inside the furnace after replacement of 4 standard burners.

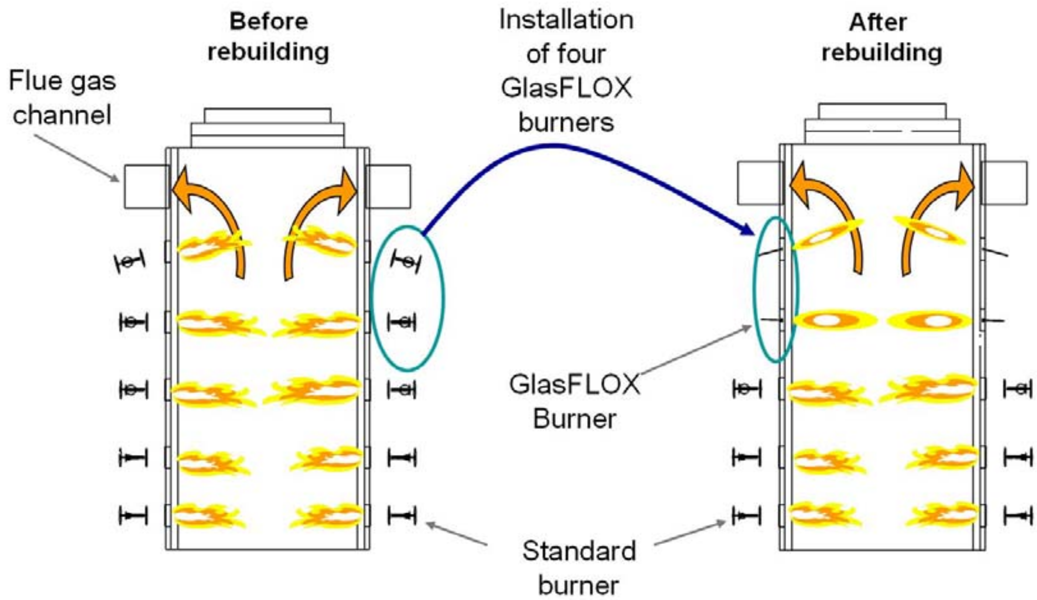

Fig. 3: Replacement of 4 standard burners through GlasFLOX® burners

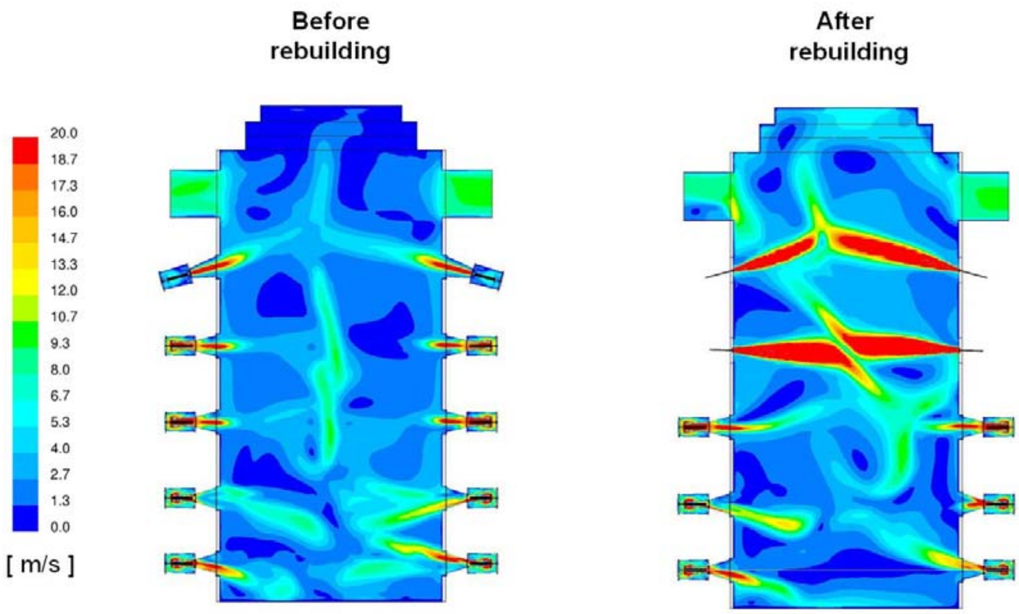

Fig. 4: Calculated velocity distribution in the OSRAM furnace after replacement

According to the experimental tests of this first step of replacement with 4 GlasFLOX® burners a NO_x reduction of roughly 10 % could be realized.
Because of these positive experiences with the new burners, the project partners decided to replace 8 of 10 burners in a second work step, see Figure 5. Only the two burners close to the batch were realized as standard burners to minimize the carry over. Again, the burners were designed and tested at GWI. Extensive numerical simulations have been carried out to get information about the flow and temperature fields in the furnace. To avoid the direct impingement of the flames of the opposite burners, various angles of the GlasFLOX® burners were realized in the calculations.

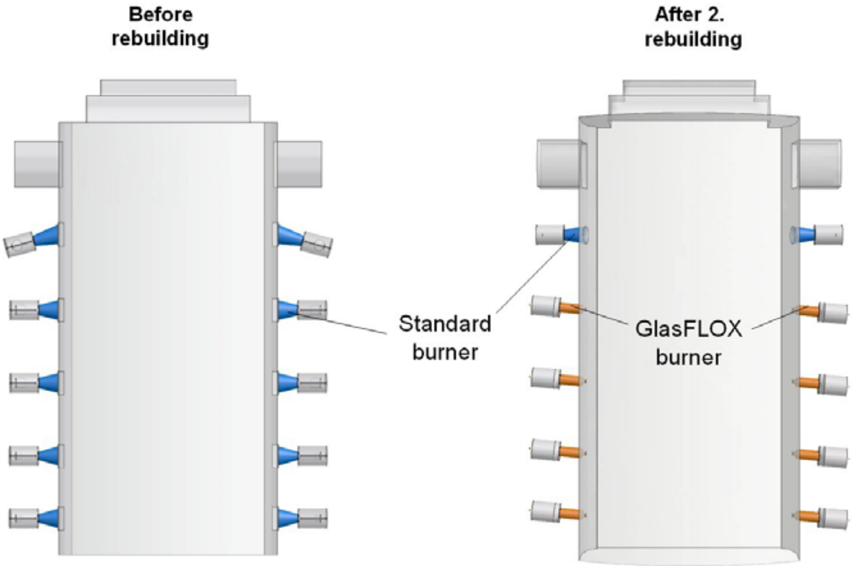

Fig. 5: Replacement of 8 standard burners through GlasFLOX® burners

In Figure 6 is shown the influence of the alignment of the burners on the velocity distribution in the furnace. The burner position is directly opposite and therefore the GlasFLOX® burners have to be inclined some degrees, because the jets collide and the flow disturb the glass bath surface. For this case an optimize angle of the burner is 5 degrees.

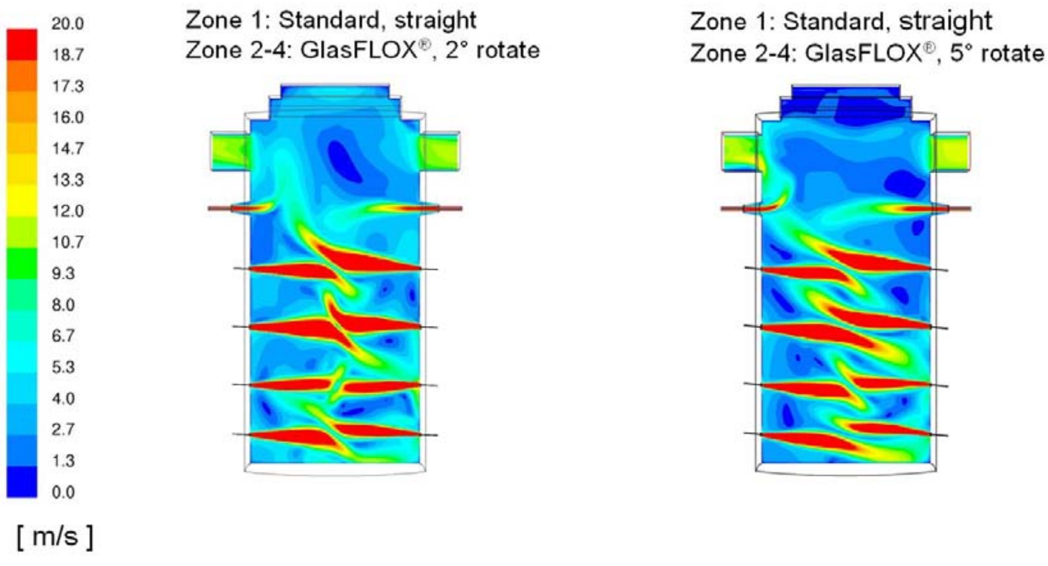

Fig. 6: Calculated velocity distribution in the OSRAM furnace after 2nd replacement – different variants

After putting the furnace into operation again, concluding measurements showed a NO_x reduction of 50 % compared to the initial state of the furnace. A still ongoing long term study will give information about the energy consumption of the furnace.
Since several months the furnace is successful in operation with permanent low-level NO_x emissions. Furthermore the GlasFLOX® burners are robust and could be operated in partial load with just a slightly increase of NO_x emission level.

Acknowledgement

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