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A technology comparison concerning scale dependencies of industrial furnaces. A case study of glass production.

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Abstract

Industrial furnaces are analyzed continuously to identify optimization potentials. Process data from the glass industry suggest that the size of a plant has an important influence on the specific energy consumption. This leads to incorrect results when using key performance indicators (KPIs) for comparison purposes. Therefore, the evaluation of innovative industrial technologies, as the use of microwaves, is often affected by incomplete assumptions, since economies of scale are often disregarded. A thermodynamic model for energy consumption was developed for analysing the scale dependencies on the specific energy consumption. It contains a correction factor for KPIs. This factor will be compared and validated with industrial process data from literature and databases as well as experimental data for the microwave process. The paper shows the impact of existing scale dependencies and their importance for a comprehensive technology comparison.

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Keywords: KPI; economies of scale; thermodynamic model; energy consumption; glass

1. Introduction

Nowadays, energy efficiency plays an important role in energy intensive industrial processes. The European Union set a 20% energy efficiency target by 2020 for all stages of the energy chain from production to final consumption. Therefore, energy benchmarking of industrial furnaces and their processes is a necessary task.

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Nomenclature

$\dot{H}_{F,ch}$	Chemical enthalpy of fuel	$\dot{H}_{FG,ch}$	Chemical enthalpy of flue gases
$\dot{H}_{F,cal}$	Caloric enthalpy of fuel	$\dot{H}_{FG,cal}$	Caloric enthalpy of flue gases
$\dot{H}_{A,cal}$	Caloric enthalpy of combustion air	$\dot{H}_{LF,cal}$	Caloric enthalpy of leak flue gases
$\dot{H}_{EA,cal}$	Caloric enthalpy of excess air	$\dot{H''}_{G,cal}$	Caloric enthalpy of goods
$\dot{Q}_{El}$	Electric energy	$\dot{H}''_{AG,cal}$	Caloric enthalpy of auxiliary material
$\dot{H}'_{G,cal}$	Caloric enthalpy of goods	$\dot{Q}_{C}$	Heat loss through cooling
$\dot{H}'_{AG,cal}$	Caloric enthalpy of auxiliary material	$\dot{Q}_{W}$	Heat loss through walls
$\dot{Q}_{ch}$	Chemical enthalpy of non-fuel	$\dot{Q}_{R}$	Heat loss through radiation from gaps
$\dot{E}$	Other sources	$\dot{Q}_{Tr}$	Enthalpy of transformation

It is needed to identify optimization potentials and energy efficiency management strategies. An additional promising way is the development of alternative technologies. These technologies might have a chance to contribute to an energy reduction in energy intensive industries. The glass production is one of the most energy intensive industries in Europe by today resulting in high energy consumption. Glass with its many applications and products, which can be manufactured from it, plays an important role in technological processes in industry with a high consumption of glass of 60-80 kg per head of population per year [1]. Process data from the glass industry suggest that the size of a plant or the scale of operations have an important influence on the specific energy consumption. This leads to incorrect results when using key performance indicators (KPIs) for comparison purposes due to different limitations. Therefore, the evaluation of innovative industrial processes is often affected by incomplete assumptions, since economies of scale are often disregarded. Nevertheless, innovative concepts for the energy intensive glass technology sector exist. The microwave process was identified as a new and innovative technology promising a reduction of energy consumption in glass production. A comparison of those innovative technologies with conventional ones is challenging. In order to give an easy and fair comparison method, this paper presents a thermodynamic model, which was created for analyzing the scale dependencies as well as the specific energy consumption, which can be determined for different plants and sizes. This leads to a better comparison for innovative and conventional concepts with different conditions. It contains a correction factor for KPIs. This factor will be compared and validated with industrial process data from literature and databases as well as experimental data for the microwave process. Following the basic principles of a technology portfolio (TPF) analysis, the results are finally presented in a modified and streamlined portfolio matrix with five technology-based potentials for development taking into account the relevance of economies of scale applied for a case study in the field of glass production for validation purposes.

2. Thermodynamic model development for energy consumption

2.1. Glass production

The process of glass production consists of melting selected raw materials (the so called batch) in a glass furnace and afterwards processing the melt further to form the required product. Due to the fact that the processing technologies are very different, the melting capacities of the different furnaces are also very different and vary from some kilogram per day up to 800 and more tons per day. Most of the glass furnaces are operated in continuous processes using fossil fuels. Electricity is often used as an additional heating source, whereas fully electric furnaces are operated solely within the manufacturing of special glasses in low quantities. A very well-known type of continuously working furnaces is the glass tank furnace using regenerators with a periodic change of flame direction. [1] The operation temperature of a tank furnace lies between 1.450°C and 1.650°C and causes a high specific energy consumption in glass production. This fact is often associated with a low thermal efficiency of conventional plants. For this reason, microwave heating has been identified as a potential replacement technology for conventionally heated, gas-fired glass melting furnaces.