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Reducing the CO_2 emissions in Croatian cement industry

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ABSTRACT

Cement industry is one of the largest carbon emitting industrial sectors. It is responsible for about 5% of anthropogenic CO_2 in the world. Therefore, it is a relevant industrial sector for CO_2 emission regulation strategies. Bearing in mind the importance of cement industry in Croatia, and because of the fact that Croatia will soon become an EU member state, the present paper analyses the potential to reduce CO_2 emission in the Croatian cement industry. There are several measures that can reduce CO_2 emissions from the cement manufacturing process: the use of waste heat as an alternative source of energy; CO_2 capture and storage technologies; reduction of clinker to cement ratio; the use of alternative and biomass fuels; the use of alternative raw materials; an energy efficient combustion process. The most energy efficient technology for cement manufacturing today is the use of a rotary kiln together with a multi-stage preheater and a calciner. Since the use of cement calciners is a relatively new technology, further improvement of their operating conditions is still needed. This paper also highlights the results of research in the field of computational fluid dynamic (CFD) simulations that are used for the investigation of process and combustion emissions. The above mentioned measures together with numerical investigations can reduce the effect of cement manufacturing in Croatia on the environment and can make it more competitive with cement manufacturers from the EU.

1. Introduction

There is indisputable evidence that the build-up of man-made greenhouse gases in atmosphere cause changes in the global climate that will have increasingly severe human, environmental and economic impacts over the coming years [1]. Climate change problems are addressed by two major international agreements: the 1992 United Nations Framework Convention on Climate Change (UNFCCC) and the 1997 Kyoto Protocol. The ultimate objective of these agreements is to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the global climate system. The Republic of Croatia has been a party of the UNFCCC since 1996 and the Kyoto Protocol was ratified in 2007 with a commitment of limitation of greenhouse gas emission in the 2008–2012 period to the level of 95% of the 1990 base year [2]. In the post-Kyoto period, Croatia, as a future EU member state, has set itself the intermediate goal of reducing the overall greenhouse emissions by at least 20% by 2020, and the long-term goal of reducing its emission to 80% below 1990 levels by 2050. To reach this goal, increase of the energy efficiency comes first, followed by significant increase of the use renewable energy sources for electricity generation, transportation and other sectors [3].

Cement industry is one of the largest carbon emitting industrial sectors in the world, being the third largest carbon emitting industrial sector in the EU [4]. It contributes to about 5% of world's anthropogenic CO_2 [5,6], in the EU it accounts about 4.1% of the total CO_2 emissions [7]. Since the EU has proved to be a frontrunner in implementing the emission reduction targets and addressing climate change, in 2005, the EU Emissions Trading Scheme (EU ETS) for greenhouse gases was launched [8]. Cement manufacturers within the EU are obliged to participate in this trading scheme, due to high CO_2 emissions. Cement production is not only a source of combustion related CO_2 emissions, but it is also the largest sources of industrial process related CO_2 emissions in Croatia, and therefore CO_2 reduction measures will be required to keep cement industry emissions in line with levels set in Kyoto and post-Kyoto period. During the cement manufacturing process almost 90% of CO_2 is emitted from two thermo-chemical processes which occur in the process of cement production. One is the calcination process, which contributes with 50% of CO_2 emission, and the other is the combustion of the solid fuels, which contributes with 40% of CO_2 emission. Remaining 10% of CO_2 are emitted during the transport of raw material and some other production processes. The only way to reduce the CO_2 emission from the calcination process is to use alternative raw materials, but so far there have been no such materials from which that kind of cement, with at least as

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good performance and durability characteristics as the current Portland-based cements, could be produced. Following this fact Gartner [9] studied the alternative hydraulic cements to lower CO_2 emissions. The study showed that with replacing the limestone with different raw materials for cement production, a CO_2 emission reduction can be achieved, but the product will be too expensive to the consumer. That is why, for now, the only way to reduce the CO_2 emission is to use more fuel efficient technologies. The best available technology, the one with the lowest energy consumption, for the cement manufacturing today, is the use of a rotary kiln together with a calciner. Szabo et al. [4] reported that an energy consumption decrease of 8–11% can be achieved if a cement calciner is used prior to the rotary kiln. The calciner is a separate furnace in which the calcination process occurs, and after that the material goes to the rotary kiln where the clinkering process occurs. This improvement in the energy consumption, by simply dividing the calcination and the clinkering process, can be calculated also as a CO_2 emission reduction.

Because cement calciners are relatively a new technology in the cement manufacturing process, further improvements of their operating conditions are needed. With the aim of improving the operating conditions, different calciners, as well as the chemical and physical processes occurring inside the calciner [10], have been studied. Huanpeng et al. [11] using a two-dimensional model and the kinetic theory of granular flow to represent the transport properties of the solid phase, studied the influence of different parameters on the dynamics of the two-phase flow in a calciner. Iliuta et al. [12] based on the reaction–diffusion approach for combustion and calcination developed a mathematical model for an in-line low-NO_x calciner. Fidaros et al. [13] demonstrated a numerical model and a parametric study of the gaseous flow and the transport processes taking place in a vertical industrial low NO_x calciner. The study showed good predictions for velocity, temperature and distribution of particles.

Aside from the studies investigating the cement production, due to the increased environmental awareness, several studies investigated environmental aspects and in particular, the potential of CO_2 emission reduction in this sector. Hence, in [14] relatively high economic and environmental effectiveness of climate change mitigation measures has been demonstrated for Macedonian industrial sector, including cement industry. Furthermore, Mokrzycki et al. [15] presented the economical and ecological benefits of using alternative fuels in Polish cement plants. The study, for the presented two cement plants, shows that combustion of alternative fuels is an environmentally friendly method of waste utilization. Mokrzycki and Uliasz-Bocheńczyk [16] demonstrated the types of alternative fuels that can be used for the combustion in the cement manufacturing process, showing that the use of wastes as alternative fuels also reduces energy costs of cement production. Fodor and Klemeš [17] studied the use of waste as an alternative fuel and discussed the applicability and limitations of current and developing waste-to-energy technologies. The study focuses on how the different technologies are being developed, to enable energy to be produced from different types of waste, while simultaneously minimizing emissions. Kääntee et al. [18] studied the use of alternative fuels in the cement manufacturing process. The study provides useful data for the optimization of the manufacturing process when alternative fuels, instead of conventional fossil fuels, are used for the combustion. Because shredder dust is an industrial by-product which must be disposed in an environmental friendly way, Kakimoto et al. [19] examined the effectiveness of the use of fine-grained shredder dust as a cement admixture. First they crushed the molten shredder dust and then mixed it with the ordinary Portland cement to form a new cement mortar. The new cement mortar was then tested, and the results of this test showed that the long-term strength of cement was not deteriorated. Bassioni [20] reported that the use of up to 5% limestone as an admixture in the ordinary Portland cement, does not affect its performance, and in the same time minimizes the CO_2 emissions from the cement manufacturing process. In order to reduce the energy consumption in the cement manufacturing process, since approximately 40% of the total input energy is being lost, Wang et al. [21] studied the use of a cogeneration power plant in cement industry. The cogeneration plant in a cement plant could recover the heat lost through hot flue gases and cooler stack, and in that way generate electrical energy and reduce the CO_2 emissions from the cement manufacturing process. Since CO_2 emissions from the industrial sectors, one of them the cement industry, are major contributors to the global warming, Wang et al. [22] studied the capturing the CO_2 from the flue gases. Worrel et al. [23] made an in-depth analysis of the US cement industry, showing that the use of blended cement in cement manufacturing process is the most efficient method for CO_2 emission reduction. Jaber [24] reported that the cement industry in Jordan is the industrial sector with highest CO_2 emissions. To achieve an annual reduction of 90,000 tonnes of CO_2 emitted from Jordanian cement industry, an increase in the energy efficiency of the grinding and the calcination process is needed.

The purpose of this paper is to analyse the current status of Croatian cement industry and the possibilities of reducing the CO_2 emissions. The development of the Croatian cement industry was analysed with different scenarios. These scenarios show that there is a possibility for a more sustainable development of this industrial sector in Croatia. In addition, a previously developed mathematical model of the calcination process [10], which contains the relevant physical and chemical processes as, e.g., Arrhenius rate approach, pressure limitation, diffusion resistance, porosity, tortuosity, pore size and pore efficiency, was used for the numerical investigation of a cement calciner. By using this detailed mathematical model, a progress in understanding of the thermo-chemical processes occurring inside a calciner was made. The results gained by this numerical simulation show that CFD can be a useful tool for the optimization of the calciner's operating conditions. Hence, by using CFD and optimizing calciner's operating conditions, less fuel will be used, and therefore a decrease of CO_2 emissions will be achieved.

2. Cement production in Croatia

Production of cement and clinker in Croatian cement plants is based on the dry kiln process. There are five operating cement plants in Croatia (Table 1), which produce Ordinary Portland Cement. Three of them have multi-stage cyclone preheater plus a calciner in their kiln process, and rest two have a multi-stage cyclone preheater kiln process. The general decline in economic activity during the period 1991–1995, particularly because of the war in Croatia, led to a reduction in cement production. However, in 1996, cement production began to rise until 2003, while in the period 2003–2008 the production was almost at same level. The another decline in economic activity, primarily due to recession and the related economic downturn during the period 2008–2010, led

Table 1
Cement plants currently (2011) operating in Croatia.

Group	Plant
Cemex	Sveti Juraj
	Sveti Kajo
	10. kolovoz
Holcim	Koromačno
Nexe	Našice