CHAPTER I

INTRODUCTION

1.1 Introduction

Cement is considered as one of the most important building materials around the world. It is primarily used for the production of concrete (Hendriks et al., 2004). The cement production ranks among the most energy intensive industrial processes, for which energy expenditure alone typically accounts for 30-40% of the production cost (Rasul et al., 2005). Energy consumption by the cement industry is estimated at approximately 2% of the global primary energy consumption, or near to 5% of the total global industrial energy consumption (Hendriks et al., 2004). This high energy intensity industry should profit a great magnitude with efforts in minimizing energy use, or in the methods and techniques of saving energy (Kolip et al., 2010).

Three major air pollutants are released to the atmosphere during the cement production process, i.e. nitrogen oxides (NO_x), carbon monoxide (CO), and particulate matter (PM). Cement production process also results in the emission of carbon dioxide (CO_2), a greenhouse gas released during pyroprocessing and calcination (U.S. EPA Sector Strategies Program, 2006). Energy efficiency improvement to the process of cement production can often be an inexpensive opportunity to reduce the emissions of major air pollutants and greenhouse gas (Sogut et al., 2009).

The cement production industry can be considered very critical from the socio-economic point of view due to its high energy consumption, as well as high emissions of major air pollutants and greenhouse gas (Rasul et al., 2005). The industry is continuously investigating and adopting more energy-efficient technologies to improve its profitability and competitiveness, and to cope up with the stringent emission requirements set by the authorities as of late. Numerous energetic and exergetic studies have previously been performed on individual phases of the cement production process, i.e. raw mill, rotary kiln, and etc., as well as the whole process of cement production.

Sogut et al. (2009) assessed the thermal performance of a trass-mill in a cement plant based on the actual operational data using energy and exergy analyses method, and successfully described the energy consumption and losses throughout the production process. Meanwhile, Schuer et al. (1992) presented the energy consumption values and described the electrical and thermal energy saving opportunities for the German cement industry. Engin et al. (2004), on the other hand, made an energy audit analysis of a dry type rotary kiln system working in a cement plant in Turkey and found that about 40% of the total input energy was lost through hot flue gas, cooler stack and kiln shell. They also showed that 15.6% of the total input energy could be recovered.

Rasul et al. (2005) assessed the thermal performance and energy conservation opportunities of the cement industry in Indonesia. This study had focused on the first law and the second law efficiencies of the kiln system as well as the cooler system, and had identified the major thermal energy conservation opportunity, i.e. via waste heat recovery. Nowak and Borsukiewicz-Gozdur (2009) had performed a study on the waste heat energy utilization from the process of burning cement clinker in the power station via supercritical organic cycle. The waste heat available from cooler stack was proven to be of benefit after its conversion to electrical energy.

Karbassi et al. (2010) investigated the role of Iranian cement industry towards the contribution of greenhouse gases. They had performed the strength, the weakness, the opportunity and the threat technique analyses in order to conclude that the best strategy to combat greenhouse gases in the Iranian cement industry is to implement energy efficiency measures.

Worrell et al. (2000) performed an in-depth analysis on the US cement industry, identifying cost-effective energy efficiency measures and potentials. Thirty energy-efficient technologies and measures had been identified. The energy savings, carbon dioxide savings, investment costs, and operation and maintenance costs for each of the measures were determined accordingly. An energy conservation supply curve for the US cement industry had been constructed, concluding a total cost-effective energy saving of 11% of the year 1994 energy use for cement making and a saving of 5% of the year 1994 carbon dioxide emissions.

1.2 Motivation of Study

Despite the numerous thermal performance studies performed on the cement production process, there has been a lack of extensive studies on the energetic and exergetic performance of the clinker cooling system, and particularly on how the operational parameters of the cooler affect its performance. A bulk of previous the studies had focused on the more energy intensive phases of the cement production process, such as the raw mill and the rotary kiln. In depth analysis on how the operational parameters of the cooler affect the exergetic performance of the clinker cooler will further assist in the optimization of the energy process.

The cost of energy, i.e. fossil fuel and electricity had been continuously elevating over the years due to the further depleting sources. It is without saying that cost is a major concern in operating a business, and the huge volume involved in manufacturing cement calls for a need to explore new ways to reduce the cost of energy. There is a limited amount of studies that had presented the cost benefit from running an energy efficient clinker cooling system. This situation provides an opportunity to present the forecasted amount of cost saving from the energy saved by optimizing the operational parameters of the cooler.

Another important benefit from optimizing the energy efficiency of a cement production phase is the reduction in emission of major air pollutants, as well as the greenhouse gas CO_2. A number of studies have shown the extent to which the cooler may affect the volume of CO_2 emission. However, it can be said that hardly any study had focused on the impact of optimization of cooler efficiency on emissions of major air pollutants such as NO_x, CO and PM. With measures currently taken by the authorities toward providing a greener environment, extensive analysis on emission reductions will further provide a strong support in improving the energy efficiency of the cement production process, and particularly the clinker cooling system.

1.3 Objectives

The goal of this study is to improve the efficiency of a grate clinker cooling system in a typical Portland cement production plant employing a dry process, which consequently reduces the cost of energy and the emissions of air pollutants and greenhouse gas. The goal is achieved through successive implementations of three objectives:

i) To determine the operational parameters of the clinker grate cooling system that affect its performance by means of energetic and exergetic analyses;

ii) To perform cost benefit analysis from the optimized cooler;

iii) To perform emission reduction analysis from the optimized cooler.

Comparisons shall be made to determine the improvements for all the three aspects aforementioned. Figure 1.3 shows the flow diagram of the objectives, methods and outputs of the study.

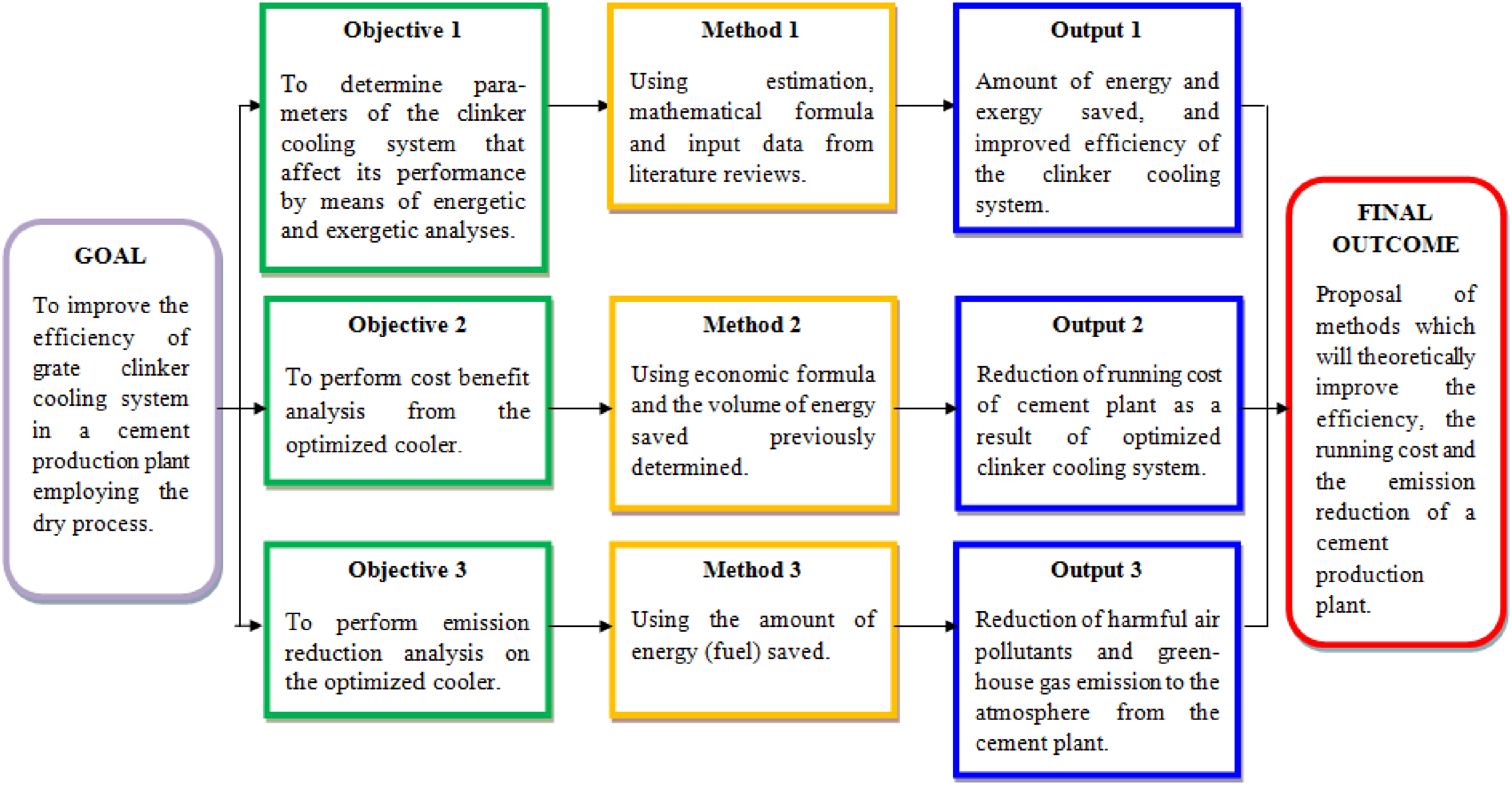

Figure 1.3
Objectives and methodologies

1.4 Scope of Study

The study focuses on the thermal performance of the clinker cooling system in a cement production plant employing the dry process. The aim is to study how the operational parameters, i.e. cooling air input rate and temperature, clinker input rate and grate speed, affect the energetic and exergetic performance of the clinker cooler.

Energy and exergy analyses can provide two different views of the considered thermal process. The interest to perform exergy analysis arises from the need to discover the causes and to quantitatively estimate the magnitude of imperfection of a thermal process. Exergy analysis leads to a better understanding on the influence of thermodynamic phenomena on the process effectiveness, and the determination of the most effective ways of improving the process under consideration.

The optimization of the aforementioned operational parameters will result in a more energy efficient clinker cooling system. Consequently, this results in the reduction of cost incurred in procuring energy. The study intends to predict the amount of annual cost savings that had resulted from the improvements made only on the cooler, using economic formulas adapted from literature reviews performed.

The scope of study also includes determining the amount of emission reduction of major air pollutants such as NO_x, CO and PM, as well as greenhouse gas CO_2 after the optimization of each of the operational parameters of the clinker cooling system. The reduction in emission is an indirect result of the declined amount of thermal energy consumption.

1.5 Research Report Structure

Chapter I: Introduction briefly summarizes the energetic and the exergetic, as well as the cost and the emission reduction benefit studies that had been performed by previous scholars on the cement production process. It then introduces the opportunity to perform a study on the thermal performance of the grate clinker cooling system, as well as the objectives that need to be implemented to successfully achieve the goal. The chapter lastly includes the scope of study, a section which explains the approach and the boundaries in conducting analyses.

Chapter II: Literature Review explains the current trend in the cement industry energy usage and emission. It also introduces the general concept of cement production process, focusing particularly on the grate clinker cooler and the energy efficiency improvement opportunities. Previous studies on the energetic and exergetic analyses of the grate clinker cooler and their operational parameters are summarized in the last two subchapters.

Chapter III: Methodology is a brief description of the methodology for the study. This includes methods to analyze the first and the second law efficiencies of the grate clinker cooling system, i.e. by studying the individual energy and exergy input and output through the system. A set of assumptions are also presented to guide the study. The second part of the chapter introduces several methods to calculate the cost savings, directly from the amount of energy saved by optimizing the operational parameters of the grate clinker cooler. The last subchapter is dedicated to the method of performing emission reduction as a result of energy savings.

Chapter IV: Results & Discussions first analyzes the energy and exergy interactions of the base case grate clinker cooler using idealized theoretical data. The first and the second law efficiencies of this system serves as a benchmark for the optimization of the operational parameters. The chapter then discusses the results of optimizing cooling air mass flow rate and temperature, clinker mass flow rate, grate speed, and heat recovery of exhaust air, in terms of improvements in the first and the second law efficiencies. The increment in energy requirement for the optimized system is also discussed in the subchapters. The energy and cost savings for the optimization of each operational parameter of the grate clinker cooling system are first studied without taking into account the cost incurred for the system's improvement, or the additional cost of energy consumed. The chapter then determines the payback period, the present value of investment, the capital recovery factor and the cost of energy conserved for each parameter from the optimization performed. Lastly the chapter discusses the amount of emission reduction achievable with the amount of energy saved as a result of the increment in the system's first and second law efficiencies.

Chapter V: Conclusion & Recommendations concludes the findings of the analyses done on the operational parameters of the grate clinker cooler. The improvements in the abovementioned efficiencies are summarized for each operational parameter. The cost benefit and emission reduction of these optimizations are emphasized on to paint a better picture on which operational parameter is the most crucial to be optimized.