Abstract

Cement industry ranks 2nd in energy consumption among the industries in India. It is one of the major emitter of CO2, due to combustion of fossil fuel and calcination process. As the huge amount of CO2 emissions cause severe environment problems, the efficient and effective utilization of energy is a major concern in Indian cement industry. The main objective of the research work is to assess the energy consumption and energy conservation of the Indian cement industry and to predict future trends in cement production and reduction of CO2 emissions. In order to achieve this objective, a detailed energy and exergy analysis of a typical cement plant in Kerala was carried out. The data on fuel usage, electricity consumption, amount of clinker and cement production were also collected from a few selected cement industries in India for the period 2001 - 2010 and the CO2 emissions were estimated. A complete decomposition method was used for the analysis of change in CO2 emissions during the period 2001 - 2010 by categorising the cement industries according to the specific thermal energy consumption. A basic forecasting model for the cement production trend was developed by using the system dynamic approach and the model was validated with the data collected from the selected cement industries. The cement production and CO2 emissions from the industries were also predicted with the base year as 2010. The sensitivity analysis of the forecasting model was conducted and found satisfactory. The model was then modified for the total cement production in India to predict the cement production and CO2 emissions for the next 21 years under three different scenarios. The parameters that influence CO2 emissions like population and GDP growth rate, demand of cement and its production, clinker consumption and energy utilization are incorporated in these scenarios. The existing growth rate of the population and cement production in the year 2010 were used in the baseline scenario. In the scenario-1 (S1) the growth rate of population was assumed to be gradually decreasing and finally reach zero by the year 2030, while in scenario-2 (S2) a faster decline in the growth rate was assumed such that zero growth rate is achieved in the year 2020. The mitigation strategies
for the reduction of CO₂ emissions from the cement production were identified and analyzed in the energy management scenario.

The energy and exergy analysis of the raw mill of the cement plant revealed that the exergy utilization was worse than energy utilization. The energy analysis of the kiln system showed that around 38% of heat energy is wasted through exhaust gases of the preheater and cooler of the kiln system. This could be recovered by the waste heat recovery system. A secondary insulation shell was also recommended for the kiln in the plant in order to prevent heat loss and enhance the efficiency of the plant. The decomposition analysis of the change in CO₂ emissions during 2001-2010 showed that the activity effect was the main factor for CO₂ emissions for the cement industries since it is directly dependent on economic growth of the country. The forecasting model showed that 15.22% and 29.44% of CO₂ emissions reduction can be achieved by the year 2030 in scenario-1 (S1) and scenario-2 (S2) respectively. In analysing the energy management scenario, it was assumed that 25% of electrical energy supply to the cement plants is replaced by renewable energy. The analysis revealed that the recovery of waste heat and the use of renewable energy could lead to decline in CO₂ emissions 7.1% for baseline scenario, 10.9% in scenario-1 (S1) and 11.16% in scenario-2 (S2) in 2030. The combined scenario considering population stabilization by the year 2020, 25% of contribution from renewable energy sources of the cement industry and 38% thermal energy from the waste heat streams shows that CO₂ emissions from Indian cement industry could be reduced by nearly 37% in the year 2030. This would reduce a substantial level of greenhouse gas load to the environment.

The cement industry will remain one of the critical sectors for India to meet its CO₂ emissions reduction target. India’s cement production will continue to grow in the near future due to its GDP growth. The control of population, improvement in plant efficiency and use of renewable energy are the important options for the mitigation of CO₂ emissions from Indian cement industries.

**Keywords:** Cement industry, energy and exergy analysis, waste heat recovery system, complete decomposition analysis, system dynamic model, CO₂ emissions