Operational Optimization of a Municipal Waste Incinerator

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As part of an ongoing modernization program, Brais, Malouin and Associates (BMA) recently undertook the simulation of a municipal waste incinerator, with the ultimate goal of reducing pollutant emissions and improving the overall efficiency of the process.

This incinerator in question (shown in Figure 1) is used to burn municipal waste composed of organic and inorganic matter on the primary (A) and finishing (B) grates. The incinerator has been modified over the years in order to dispose of additional waste such as dried sewage sludge, which is injected as pulverized particles (C). Over fire air is injected on the front and rear walls (D). Additionally, 8% of the hot flue gases are extracted at port (E) and used to dry the sewage sludge. The humidified flue gases are then re-injected into the incinerator (F) in order to destroy the odors resulting from the VOC's (Volatile Organic Compounds) emanating from the drying of the sewage sludge. Current operational data showed highly fluctuating levels of carbon monoxide, which sometimes exceeded new emission standards. BMA's goal was to find solutions to this problem.

In order to tackle this task, a new 7-stream combustion model was developed by BMA to take into account for multiple streams of fuels of varying composition and humidity. Five of the streams represent different fuel and FGR (Flu Gas Recirculation) compositions, while the two remaining streams represent dry air and water vapor.

Four of the five fuel streams are for waste fuels; one extra fuel stream was included in the model to account for an auxiliary natural gas burner, which seemed likely to be needed. The streams were modeled by the transport of conserved scalars representing the mass fraction of each of the fuels, dry air and water vapor. Water vapor is accounted for separately because the concentration of water vapor varies greatly from stream to stream.

The local mixture fraction for each of the fuels was obtained by dividing the local mass of available air and water vapor between each of the fuel streams. Each fuel was assumed to react independently.

The reactions were modeled using a chemical equilibrium hypothesis. Local chemical equilibrium was modeled by minimization of Gibbs free energy. The combustion products were then recombined to yield the local concentration of chemical species, which were passed back to STAR-CD via the User subroutines. The burning process on the grates (A and B) was modeled externally using a simple pyrolysis model yielding combustion hot product streams composed of CO, CO_2, SO, SO_2, H_2, H_2O and N_2. The distribution of the waste and by-pass air on the combustion grates was modeled as air and pyrolysis product inlets disposed in a checkerboard fashion. The dried sludge stream (C) was modeled using Lagrangian particle tracking.

An initial steady-state simulation was carried out using flow rates obtained from the operational data logs. The flame contours shown in Figure 2 closely resembled those observed through the incinerator's viewports by BMA's field engineers. The streamlines shown in Figure 3 show the flow patterns inside the incinerator. Temperature contours on the incinerators' centerline are shown in figure 4.
Other simulations were carried out with reduced excess air and pre-heated combustion air in order to determine the level of reduction of CO emissions that could be achieved. The simulations showed that these options would reduce CO emissions. However, the comparison of predicted emissions with the field data for current operational set points and reduced excess air showed lower predicted CO emission levels than those measured when averaged over an entire day's operation.

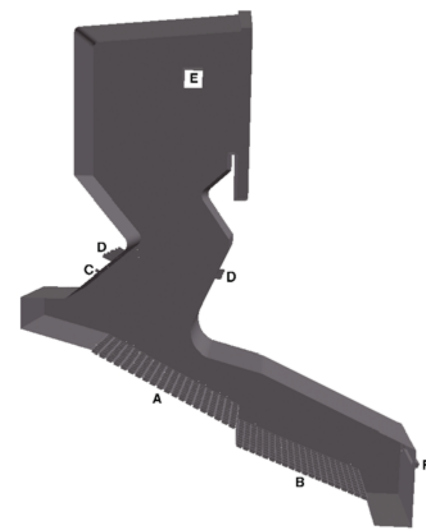
Following the presentation of these results to the engineers and operators responsible for the incinerator, the chief operator remarked that the current automated control loop was based on assuring a steady steam generation rate rather than steady state conditions for air flow and the quantity of waste being burned. The chief operator then proceeded to run his own tests by manually controlling the air flow and disposition of waste on the combustion grates. The CO emissions measured during manual control closely matched the predicted CO emission levels to within a few ppm. Furthermore, the fluctuation of CO emission levels was also greatly reduced.

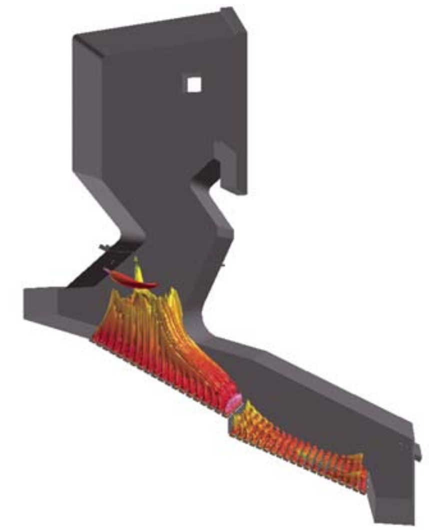
This study has shown that with the intimate knowledge afforded by STAR-CD of the combustion phenomena inside these industrial units, operators and engineers can easily devise ways of improving the process. Ongoing studies are currently being carried out to determine if further emission reductions can be achieved by further modification of the operational set-points. Other physical modifications to the incinerator are also being investigated. These include modifi-cations to the position and dimensions of the over fire air nozzles as well as the pre-heating of the humidified flue gases that were used to dry the sewage sludge prior to being re-injected into the incinerator (F).

"STAR-CD has become an essential tool for BMA engineering. It enables us to qualify quantify ways of enhancing the environmental performance and efficiency of industrial size combustion equipment", says Francois McKenty. ■

FACTS — **Gibbs free energy**

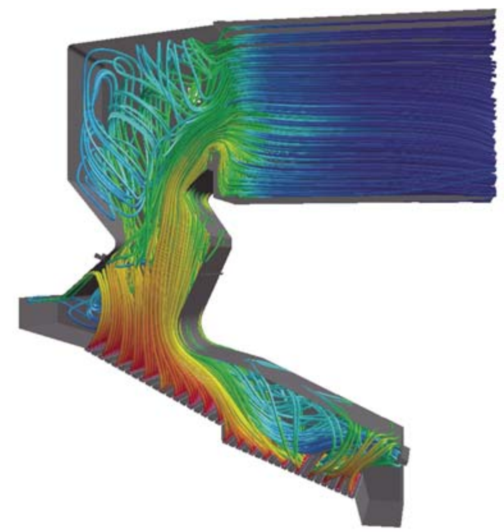
Gibbs free energy is a thermodynamic potential, which measures the "useful" work obtainable from an isothermal, isobaric thermodyamic system - Wikepedia

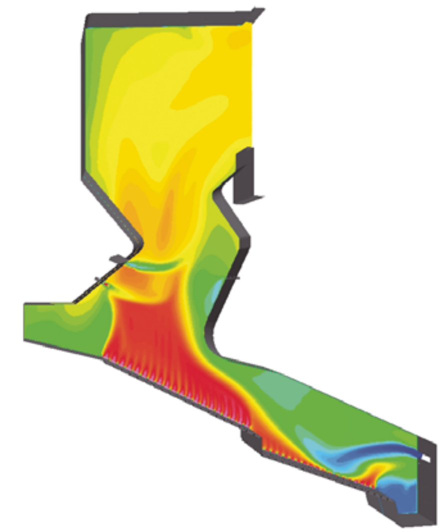




▲ Fig:01 - (left)
Schematic of incinerator

▲ Fig:02 - (right)
Flame contours





▲ Fig:03 - (left)
Flow patterns inside incinerator

▲ Fig:04 - (right)
Temperature contours on the incinerator

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