行政院國家科學委員會專題研究計畫　成果報告

旋轉窯焚化爐中廢輪胎熱裂解反應動力參數分析及流場模擬之研究(3/3)

計畫類別：個別型計畫
計畫編號：NSC93-2211-E-002-002-
執行期間：93年08月01日至94年07月31日

執行單位：國立臺灣大學生物產業機電工程學系暨研究所

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報告類型：完整報告

處理方式：本計畫可公開查詢

中　華　民　國 94年11月2日

本計劃執行延續前兩年之研究計畫，繼續進行旋轉窯之空氣污染排放量測以及旋轉窯之流場模擬。

一、空氣污染測量

在空氣污染防制發展進程上，粒狀物管制均係由質量濃度之管制開始，也因如此，目前我國環保署對固定污染源及水泥廠粒狀污染物之排放標準，亦僅規定排氣中之微粒總質量濃度。然而，除氣懸微粒總質量濃度之外，對污染防制及保障國民健康而言，微粒另一更為重要之性質為其粒徑分布。由氣懸微粒在人體呼吸道之行為討論，在以口呼吸時，粒徑小於 3 μm 之微粒約有 50％之比例可進入人體肺部之肺泡區；在以鼻呼吸時，粒徑小於 2 μm 之微粒可進入人體肺部之肺泡區，而且有 10 – 20％的微粒將停留在這個區域。由 ICRP(International Commission on Radiological Protection)於 1994 年公佈的研究結果，可以發現大部分進入人體肺部的微粒均為粒徑小的微粒，其中粒徑小於 1 μm 的微粒佔有很重要的比例。

為提供歷來研究所缺乏的旋轉窯燃燒排放微粒之粒徑分布資訊，本研究利用粒徑解析度較高之微粒個數濃度測定設備－電子式低壓衝擊盤測定儀(Electrical Low-Pressure Impactors，ELPI)，測定水泥廠廢氣排放管道排放之微粒分階個數濃度資訊，再加上粉塵監測設備(Dust Monitor，GRIMM)，量測微粒總質量濃度分布。在本研究中主要解析之微粒粒徑範圍為 0.075 ~ 10 μm。

由實驗測定結果顯示：由廢氣排放管道內截取粒徑為 0.06 μm 為微粒具有可觀之個數濃度。由廢氣排放管道內部之微粒粒徑濃度分布，可以看出其粒徑分布範圍寬廣，並不似大氣微粒大多呈現由三個對數常態分布組成之型態。由廢氣排放管道口附近之微粒粒徑濃度分布，可以看出此類製程廢氣中微粒質量濃度分布多集中於 PM1~5 之範圍中，若在背景大氣微粒具有較高之 PM5~10 濃度時，大氣環境之 PM10 測值將不再是檢視此類製程排放粒狀物影響之良好指標。排氣組成成分，仍受其高溫煅燒程序影響而以 NOx 為主。

廢氣排放管道內部之微粒分徑個數濃度如圖 1，其主要的粒徑為第 8 階，亦即截取粒徑為 1.0 μm，中位粒徑為 1.3 μm，以及第 2 階截取粒徑為 0.06 μm，中位粒徑為 0.081 μm，其個數濃度各為 4000 /cm^3 及 3000 /cm^3。在本實驗中廢氣排放管道內微粒粒徑分布之幾何標準偏差 GSD=3.264，中位粒徑為 CMD=0.415 μm。

廢氣排放管道內微粒分徑質量濃度如圖 2 所示。其重量於截取粒徑 8.0953 μm 者最大，為 1.51×10^4 $\mu g/m^3$，粒徑範圍小於 0.5 μm 之總質量濃度為 230 $\mu g/m^3$，粒徑大於 0.5 μm 微粒總質量濃度為 2.52×10^4 $\mu g/m^3$。

本研究提供了旋轉窯之微粒粒徑分布以及其質量濃度分布，以及廢氣排放管道中氣體性質及其組成成分。主要可由前述觀測結果獲致以下結論：

1. 由廢氣排放管道內之微粒分徑個數濃度資訊中，截取粒徑為 0.06

μm 為微粒具有可觀之個數濃度，惟其易因大氣擴散機制而影響下風較遠區域。

2. 由廢氣排放管道內部之微粒粒徑濃度分布，可以看出其粒徑分布範圍寬廣，並不似大氣微粒大多呈現由三個對數常態分布組成之型態。
3. 由廢氣排放管道口附近之微粒粒徑濃度分布，可以看出此類製程廢氣中微粒質量濃度分布多集中於 PM1~5 之範圍中，若在背景大氣微粒具有較高之 PM5~10 濃度時，大氣環境之 PM10 測值將不再是檢視此類製程排放粒狀物影響之良好指標。
4. 排氣組成成分，仍受其高溫煅燒程序影響而以 NOx 為主。

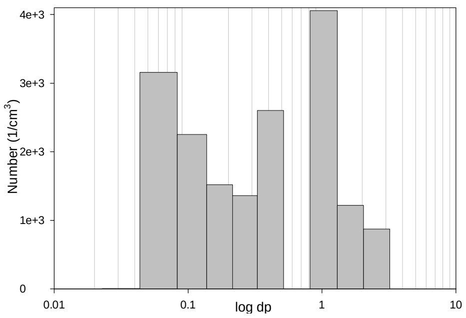

圖 1. 排放管道內微粒分徑個數濃度

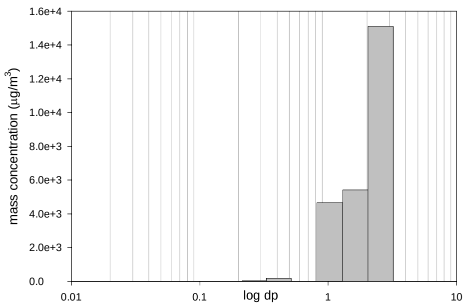

圖 2. 排放管道內微粒分徑質量濃度

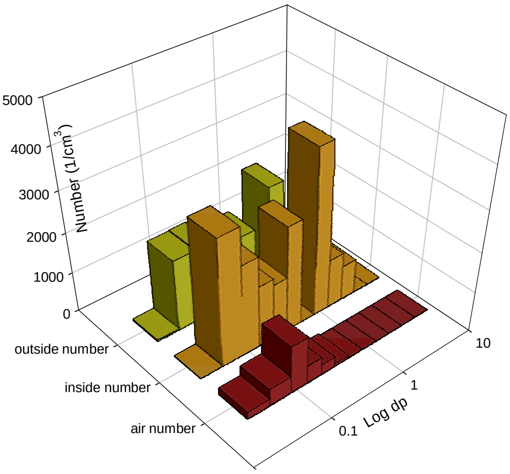

圖 3. 排放管道內外微粒粒徑比較

表 1. 廢氣排放管道氣體性質及組成

Temperature	96℃
Inner pipe	
O_2	14.2%
CO	2773 ppm
NO	1230 ppm
NO_2	4.8 ppm
NO_x	1235 ppm
CO_2	4.98%

二、旋轉窯流場模擬

利用 CFD 軟體進行旋轉窯流場模擬，先建立旋轉窯之模型，接著建立其網格，再輸入模擬軟體中，建立其邊界條件，進行有限體積之運算。

Rotary kiln incinerators are widely used for the heat treatments of many kinds of industrial wastes. Almost all locations inside a full-scale rotary kiln incinerator are inaccessible when the rotary kiln incinerator is operating. Because of this restriction, it is difficult to sufficiently understand the characteristics and the performance of the full-scale rotary kiln incinerator by experiment. Recent improvements in computer science and rapidly growing computational capacity have resulted in wide use of numerical analysis. This study utilizes a commercial CFD code to simulate a full-scale rotary kiln incinerator. The results predict the velocity distribution, temperature distribution and species concentration distributions inside a rotary kiln incinerator. The model is validated by comparison with measured temperatures. Correlation with experiment validates the simulation and demonstrates its ability to evaluate the performance of the rotary kiln incinerator.

Figure 1 shows the velocity contour and Figure 2 shows the temperature contour for a vertical slice at the x=5.715 plane that is located at the rear of the rotary kiln. Figure 1 indicates that stratified velocity of the fluid flow took place at the rear of the rotary kiln. This stratified phenomenon was not obvious for the temperature distribution in Figure 2.

Figure 3 shows the velocity contour for a vertical slice at the z=0 plane. Figure 4 shows the temperature contours with the same operating parameters at the same locations.

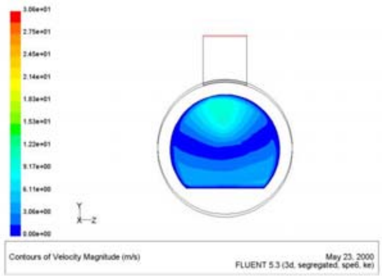

Figure 1. Velocity contour for vertical slice at x = 5.715 plane.

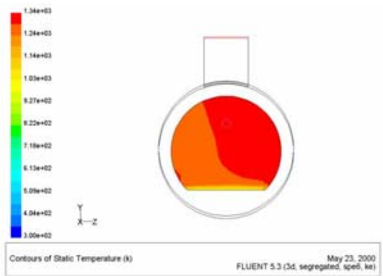

Figure 2. Temperature contour for vertical slice at x = 5.715 plane.

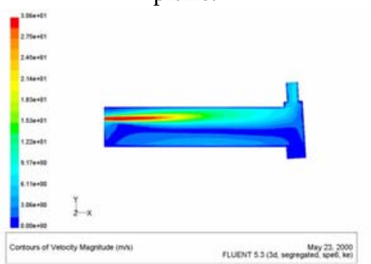

Figure 3. Velocity contour for vertical slice at z = 0 plane.

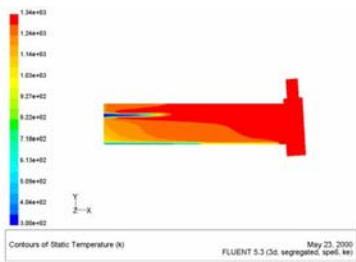

Figure 4. Temperature contour for vertical slice at z = 0 plane.

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