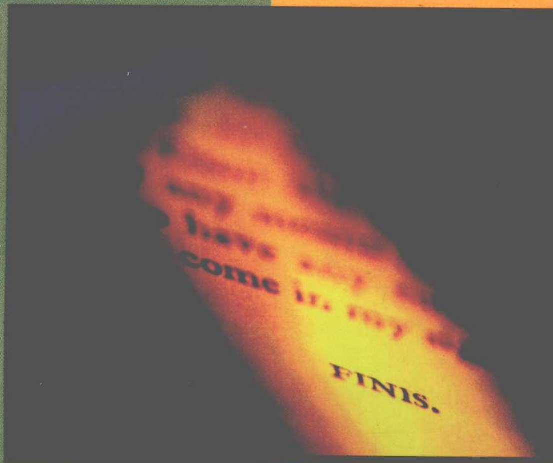
留英学者优秀论文集



吴韬 韩钟伟 主编

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前　言

本书作为一部英文学术论文集得以出版，受益于2003年7月在英国诺丁汉大学举办的第一届全英中国学生、学者学术年会。

这次学术会议得到了中国驻英使馆教育处和诺丁汉大学的大力支持，诺丁汉大学校长杨福家教授等知名专家学者应邀出席并发表了专题演讲。会议共收到来自英国二十多所大学四十多篇学术论文，其中作者大多为博士后、高级访问学者和在读博士生。他们的研究方向和研究方法在相当程度上代表了留英中国学人在各自领域学术前沿水平。

近年来中英两国之间的文化教育交流发展迅速，在英中国学者及留学生人数更是成倍增长。为了在留英学者中营造一个活跃向上的学术氛围，让国内广大高校师生和科研机构工作者了解留英学者们的学术活动情况，我们遴选了二十余篇学术论文加以整理并出版。入选论文涵盖自然科学、工程、经济、商学及管理科学等领域，这也是首部用英文形式出版的留英学生学者学术论文集。本书如能达到抛砖引玉之目的，为中国学术研究与国际接轨出力，我们就不甚欣慰了。

我们特邀了诺丁汉大学余海岁教授、伦敦米德斯堡大学姚叔洁教授等学者作为本书的顾问，对所有论文进行了审阅。当然本书中可能出现的疏漏与不妥之处由编者负全部责任。

我们愿将此书献给所有为学术节付出辛勤劳动的人们。

吴　韬　韩钟伟

2003年10月

PREFACE

The 1st Annual Academic Conference of Chinese Students and Scholars Association (CSSA) at Nottingham on Science, Engineering, Business and Economics was organized by CSSA-Nottingham on July 7, 2003.

The purpose of the Conference was to bring together the academic community of Chinese students and scholars in the United Kingdom. It aimed to provide a forum for Chinese students and scholars to present and discuss their research findings. Studies presented were on some aspects of Science, Engineering, Business and Economics, which are related to China or are of potential benefit or interest to China.

A further aim of the Conference was to encourage the discussions amongst participants that may hopefully lead to future joint/collaborative research activities.

This conference had attracted more than forty papers from around 20 UK universities. The majority of them were contributed by post doctoral research fellows, senior visiting scholars and PhD students. Papers included in this symposium were 23 papers selected from those submitted to the conference, which can represent, to some extent, the frontier of the research currently conducted by Chinese scholars and students in the UK. To be consistent with the Conference, this symposium has been divided into two sections. Section one is a collection of papers on Science and Engineering, while Section two includes all articles on Economics, Business and Managements.

We sincerely hope this symposium can help researchers in mainland China to get some general ideas about the research carried out in the UK and build up collaborative links between researchers in the UK and in mainland China.

On behalf of the editors and the organizers of the Conference, I must acknowledge and thank:

The Education Section of the Chinese Embassy in the UK and the University of Nottingham, for their financial and spiritual support;

Professors Hai-sui Yu and Shujie Yao, for their valuable suggestions and time in reviewing the articles;

The CSSA-UK and the Wang Dynasty Group, for their financial support;

Members of CSSA-Nottingham and some friends from outside Nottingham who travelled a long way to join us in the Conference, for their enthusiasm, which made the solid foundation of the Conference;

And last but not least, the Chancellor of the University of Nottingham and Honorary Chairman of the Conference, Professor Yang, Fujia, for his encouragement and great contribution to the Conference.

We very much appreciated these support, without which the Conference and this symposium would not have become reality.

Wu, Tao and Han, Zhongwei
October 2003

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THE INCLUSION OF CHAR MORPHOLOGY IN A BURNOUT MODEL

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Abstract

In this study, based on the latest image analysis system, KS 400 image analysis system, some new techniques to automatically analyze optical structures of chars obtained from a Drop-Tube furnace have been developed. The morphology data from char image analysis have been incorporated as inputs to a char burnout model based on Hurt's CBK model. It has been observed that the char combustion rate was strongly affected by char structural parameters and the inclusion of char morphology has led to a better prediction of char burnout. It has also been suggested by the model that the inclusion of ash inhibition overestimates the resistance attributed by ash film and the consideration of ash film resistance should be undertaken in a different way to give a better prediction at the later stages of char combustion.

Keywords: Image Analysis, Char Morphology, Char Burnout, Combustion Modelling

残炭形态学研究及其在粉煤燃烧模型中的应用

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本文应用 KS400 图像分析系统，开发了针对于粉煤燃烧过程中所产生残炭颗粒光学结构的自动表征系统。对 DTF 炉中采集残炭进行了系统分析。残炭形态结构分析应用于基于 Hurt CBK 模型的改进型残炭燃尽动力学模型。研究发现，残炭的形态结构对残炭燃尽过程起主导作用，在模型中引入残炭形态结构影响因素改善了残炭燃尽模型的精度。模拟计算还表明模型中对灰分对燃尽过程抑制作用的处理方法过度考虑了灰膜对燃烧过程的影响。

1. Introduction

Coal is the most abundant fossil fuel resource in the world and has played and will continue to play an essential role in the supply of energy. During pulverised fuel (pf) combustion coal particles are rapidly pyrolysed to yield char particles. Char combustion then occurs and the rate of char combustion in utility boilers plays a very important role in determining carbon loss in ash and the design of boilers and burners. Of particular interest is the prediction of char combustion from original coal properties and char structural parameters. Because of coal's diversity in rank, variation in composition and the complexity of combustion process, such work still presents many challenges.

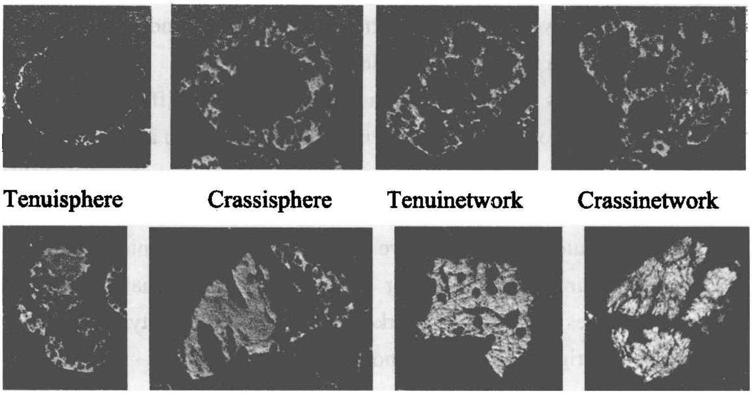
Chars produced under rapid pyrolysis condition are mainly porous carbonaceous solids. Char morphology is an empirical description of char geometry, such as char size and its appearance, its wall thickness, macroporosity, and optical anisotropy. Char particle size and its pore structure are necessary in determining the aerodynamic, and heat-mass transfer properties of particle during burning. In most models of char combustion, particles are normally assumed to be spherical, uniformly porous solids with a certain diameter. However, this is not the case in practice, and chars from the same coal can exhibit a range of morphologies and porosities.

Many investigations have focused on how to describe different structural types of char particles occurred in pulverized coal combustion and assign them into specific catergories.[1-9] A list of well-defined char types are shown in Table 1, which is based on the ICCP classification[9] and the work of Bailey[3]. Unfortunately, an automatic quantitative char classification technique, which is able to restrict char categories as far as possible and adequately describe particle morphotypes that relate to markedly different maceral types and their distribution in the original coal, is still not available.

Table 1 Char Morphology Classification[3, 9]

Particle Name	Char Shape	Unfused Material	Pore Volume	Wall Thickness
Tenuisphere	spherical to angular	<25%	>80%	>50%walls <3μm
Crassisphere	spherical to angular	<25%	>40%	>50%walls >3μm
Tenuinetwork	spherical, elongate or irregular	<25%	>70%	>50%walls <3μm
Crassinetwork	as above	<25%	40~70%	>50%walls >3μm
Inertoid	Spherical, rectangular, subspheroidal	>70%	5-40%	Variable
Fusinoid/Solid	rectangular to irregular	>70%	<5%	Solid
Mixed porous	spherical to irregular	25-70%	>60%	Variable
Mixed dense	rectangular to irregular	25-70%	40-60%	Variable
Mineroid	spherical to rectangular	——	——	Minerals>50%

Typical two-dimensional representations of these morphotypes, which have been captured under a microscope, are shown in Figure 1.



Magnification: ×32, Coal origin: Ashland, Size range: 106-125μm
Operating conditions: 1150°C, 100ms, 1% O_2

Figure 1: Typical images of different char morphotypes

Numerous char burnout models have been developed to predict the burnout for different coals. For example, the model developed by Hurt and his coworkers[12] has been widely accepted in accurately describing the kinetics of heterogeneous char oxidation reactions. Work has also been carried out to describe char forms using image analysis techniques[4, 5]. The aims of this work were to construct a model based on Hurt's CBK model and extend it by the incorporation of char morphological data from automatic char image analysis.

2. Experimental

2.1 Coal Origin and Char Preparation

Four coals were picked out for this study: Ashland, Bijao, Caypa and El Cerrejon. Results of proximate and ultimate analyses together with petrographic characteristics of these coals are shown in Table 2[1]. All these coals were ground and sieved into the size fraction of 106-125 μm. All coal samples were fed to a drop-tube furnace[1] (DTF) operating at 1300°C, 1150°C, and 1000°C respectively, with a coal feed rate of 0.1 to 0.15g/min, an oxygen concentration of 1% and a residence time of approximately 200ms, to produce chars for further investigation. To determine combustion characteristics the chars were refired on the drop-tube furnace under conditions of 1300°C, 5% oxygen and three different residence times of 200ms, 400ms and 600ms[1].

Table 2 Petrographic characteristics, proximate and ultimate analysis results[1]

Coal Origin	Moisture Wt%	Dry Basis wt%			Ultimate Analysis Data wt% daf				
		VM	FC	Ash	C	H	N	S	O
Ashland	1.3	33.1	57.8	9.2	88.91	5.71	1.85	0.78	2.75
Bijao	6.2	43.5	52.5	4.1	73.83	5.42	1.78	0.63	18.35
Caypa	2.3	38.1	59.7	2.2	85.43	5.76	1.86	0.64	6.31
El Cerrejon	3.3	37.7	58.8	3.5	83.80	5.58	1.83	0.65	8.14

Table 2 Continued

Coal Origin	Rank VRo%	Maceral Content Vol %			
		Vitrinite	Liptinite	Semifusinite	Fusinite
Ashland	0.75	68.5	14.3	4.6	12.6
Bijao	0.50	90.8	6.0	2.6	0.6
Caypa	0.59	95.2	0.4	3.6	0.8
El Cerrejon	0.59	90.6	1.6	3.2	4.6

2.2 Char Preparation

A mixture liquid of 6 parts of a liquid resin (Estratil 2195, provided by Cray Valley Ltd Spain) and 100 parts of Methyl-ethyl-ketone (50%w/w) was employed in mounting char samples. About 0.10 to 0.15 grams of char were mixed with 2 grams previously mixed resin in a plastic mould with a diameter of 25 mm. The mould was then put in a desiccator connected to a vacuum pump. Once set, 7 to 8 grams of pure resin were added on the top of the dried layer to form the bottom of the char block ready for polishing. After polishing, the samples were ready for examination under a microscope.

2.3 Image Analysis Equipment

Polished char blocks were observed under a microscope (Leitz Ortholux II POL-BK, with 32× oil immersion objective) with a flexible high performance Zeiss AxioCam digital camera installed. Images captured from the camera were stored and analysed by a KS400 image analysis system (provided by Imaging Associates Ltd, UK) installed in a PC

3. Char Image Analysis

To assign chars to different char morphotype groups, geometric parameters such as wall-thickness, char porosity, particle size, proportion of unfused material, and pore number were measured.

The initial char image captured by the digital camera attached to a microscope was converted into a binary image. Small char fragments were scraped using the "binscrap" function. The image is now ready for further processing and measurements.

To automatically perform image analysis, it is necessary to reconstruct char boundaries. It is always a problem to maintain the integrity of an individual char in char samples. Many char particles, after polishing, are broken or in fragments. Generally, there are two methods to rebuild char structures. Using a mouse, char boundaries can be recreated. However, if the gap between two fragments is large, the risk of distorting the original char shape is significant and manual reconstruction of char boundaries is also time consuming and tedious. Another approach is to do it automatically, using a combination of image processing functions. Lester et al[4] and Alvarez et al[5] tried 'dilation' and 'erosion' functions provided by image analysis software. Lester et al[4] also recommended the use of 'close' function in recreating broken char walls. The use of the dilation-erosion function combination and the close function has been tested in this study. Figure 2 shows the consequence of the dilation-erosion function combination by using KS400 Image Analysis System. Figure 3 shows how the close function works in reconstructing char boundary in KS 400 image analysis system.

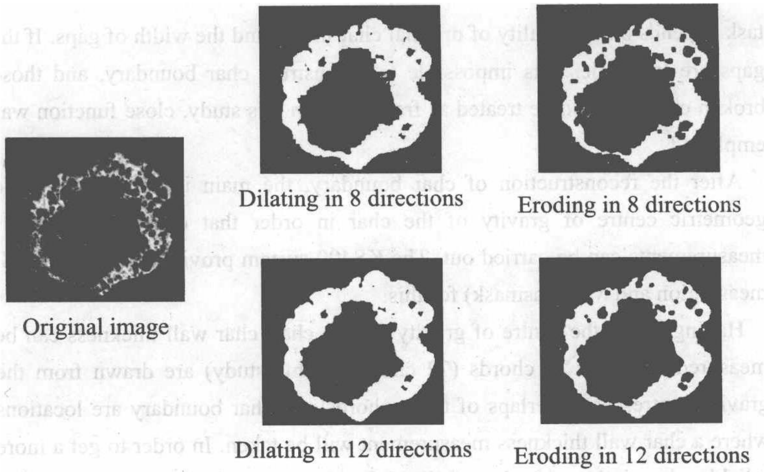


Figure 2: Reconstructing char walls by using dilation-erosion functions (Ashland coal)

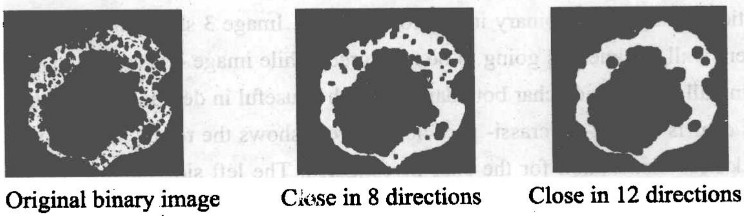


Figure 3: Reconstructing char walls by using close functions (Ashland coal)

The comparison of the dilation-erosion combination in different directions shows that for the char investigated, dilation in 8 directions, followed by erosion in 8 directions provides a char shape much closer to the original char shape. As far as close function is concerned, the same trend happens. Close in 8 directions gives a better approach in char wall reconstruction than close in 12 directions. However, as has been pointed out by Lester et al[4], the dilation-erosion combination does lead to the distortion of original shape, whereas close function demonstrates a better approach in the reconstruction of char walls. It should be pointed out that how well close function performs in such a task depends on the quality of original char image and the width of gaps. If the gaps are too wide, it is impossible to reconstruct char boundary, and those broken chars have to be treated as fragments. In this study, close function was employed.

After the reconstruction of char boundary, the main issue is to find the geometric centre of gravity of the char in order that char-wall thickness measurements can be carried out. The KS400 system provides functions (MS-measregion and MSmeasmask) for this.

Having found the centre of gravity for the char, char wall thickness can be measured. A series of chords (72 chords in this study) are drawn from the gravity centre. The overlaps of these chords and char boundary are locations where a char wall thickness measurement will be taken. In order to get a more reliable description of char wall-thickness, more chords can be drawn. However, because it is a for-loop in the image analysis program, more chords mean more processing time. Figure 4 shows the routes of char-wall thickness measurement. Image 1 is the original colour image for a crassisphere char particle. Image 2 is a binary image for that char. Image 3 shows the locations where wall thickness is going to be measured, while image 4 is an image after filling all holes inside char boundaries, which is useful in determining whether this char is a tenui- or crassi- particle. Figure 5 shows the results of char-wall thick-ness distribution for the char investigated. The left side picture is char-wall thickness distribution with secondary voids being considered, while the right side picture is without any secondary voids inside the char boundary. It is clear that this char is a crassisphere with more than 90% char walls thicker than 5μm, where secondary voids are not included in the measurement.

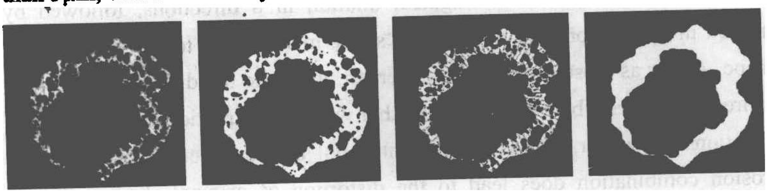


Figure 4: Sequence of char wall thickness measurement (Ashland coal)