PC IMAGE-BASED ANALYSIS SYSTEM FOR PARTICLE CHARACTERIZATION OF DEINKED PULPS

J. D. Miller
Professor
University of Utah
Salt Lake City, UT 84112
U.S.A.

C. L. Lin
Associate Professor
University of Utah
Salt Lake City, UT 84112
U,S.A.

Q. Yu
Research Associate
University of Utah
Salt Lake City, UT 84112
U.S.A.

ABSTRACT

A low cost PC image-based particle analysis system is being developed for particle characterization of deinked pulps at the University of Utah. Initial R&D efforts of such an image analysis system were made for on-line particle characterization in the mineral processing field but now it has been found to be applicable for the analysis of deinked pulps in the wastepaper recycling industry. Both the size and shape of ink particles in hand sheets and paper pulps for all three typical wastepaper resources (newsprint, xerographic, and magazine) can easily be determined by the image analysis system. Preliminary results indicate that the system is quite successful for the evaluation of products obtained from deinking air-sparged hydrocyclone (ASH) flotation tests. Quantitative analysis can give both the size and shape of ink particles for such products. In addition, the hardware and software used to implement this image analysis system are discussed. Finally, on-line instrumentation of such a system for the direct measurement of wastepaper pulp is considered as part of future research activities.

INTRODUCTION

During the past decade, advances in computer and video technologies have made it possible to develop an inexpensive instrumental method for particle characterization. The computing cost is no longer expensive, and algorithms based on image analysis are available [1] and easily programmed. Digital image analysis techniques are now widely used in many manufacturing industries as a tool for quality control, and to improve overall process efficiency. In the paper industry, image analysis techniques have been applied in many areas such as dirt count[2-5], microscopic ink particle analysis[6-8], and for other purposes.

Initial efforts for the design and development of a PC-based image analysis system were made for on-line particle characterization in the mineral processing field[9,10] but now it has been found to be applicable in other areas including the analysis of deinked pulps in the waste paper recycling industry.

This paper discusses briefly the actual design and development of a PC-based image-analysis system for particle characterization. Both the hardware and software required to implement such a system are discussed, including the interface for the special image acquisition hardware. Information regarding the implementation of the software modules is presented in detail. Also reported are preliminary results for the characterization of ink particles in both hand sheets and pulp suspension of three wastepaper resources (newspaper, xeroxpaper, and magazine) as obtained from ASH deinking flotation tests.

PC-BASED IMAGE ANALYSIS SYSTEM

There are three major components that comprise the PC-based imaging analysis system. The first is a high resolution video system to capture and to digitize the image from the microscope, the second is a personal computer fast enough to perform imaging analysis and the final component is the necessary software modules.

Hardware Considerations

The hardware components of the PC based image analysis system consist of video camera, video frame grabber and the host computer system. The video camera combined with the frame grabber are often referred to as the image-acquisition device. The important function of the image-acquisition device is to put the image into the image memory. This involves the use of a video camera to digitize the continuous image into an array of pixels (picture elements), with different intensity values, into the image memory of the frame grabber. This image memory can be read or written to the host computer for the subsequent image processing and analysis.

In selecting an appropriate video camera, the most important feature, distortion, should be taken into consideration. Low distortion is required to ensure the reliable measurement of the geometric properties of the projected particle image. For acceptable intensity and detail resolution, the required frame grabber should have an image memory capable of storing 512x512 pixels or 640x480 pixels, with each pixel having at least of 8 bits of value. With this capacity, 256 different gray levels of intensity are available. In this study, the QuickCapture DT-2855 frame grabber by Data Translation was used. This frame grabber board has a 640x480x8 bits of image memory.

In selecting a suitable host computer, the main concern is its computational power and memory. The host computer's CPU (central processing unit) should have computation power to process images within a reasonable time interval. For computer memory, 2 to 4 MB of RAM (random access memory) should be sufficient for image storage and implementing the necessary software. In this study, a CompuAdd model 425 personal computer was selected. It has a 25 MHz 80486DX chip with 4 MB of memory and a SuperVGA display monitor.

Software Implementations

The software developed for this image analysis system should have operation functions that include image capture, image processing, and measurement. In consideration of these requirements, three major classes of software modules were formulated including routines of the utilities for interface, image processing, and measurement of image objects.

Interface modules

Two kinds of interface utilities have been implemented. The first variety can be used to interface between the frame grabber and the host computer. The other interface software routines is the graphical user interface (GUI). It allows the user to communicate with the host computer through the use of a mouse and graphical icons.

For controlled programming of the frame grabber, it is important to specify the hardware address. Therefore, C programming language was used for the coding of the frame grabber interface routines. In most cases, the frame grabber has a control chip for interface purpose. A device control chip generally contains a number of control and status registers. Typically these registers can be accessed via the chip address plus an offset. This makes knowing how to specify the hardware address though the host computer very important for the interface design. The bit manipulation function of C, such as logical OR or AND combined with "bit mask" can be used to set or to clear any bit within the register. Each bit within the register can be set to perform the functions such as video control, pixel address, line address, pixel data. For example, the QuickCapture board has 14, 16-bit I/O registers for control and status purposes. The hardware address of this board is at 0x240, and the offset for pixel address is 8. The implemented subroutines for the frame grabber interface include the open/close of the hardware, read/write the pixel intensity of the image memory, and get/put line of pixels for the image memory.

One of the important features of the GUI is to deal with the user input, which can be keystrokes or mouse actions. This user input is often referred to as an event. The main components of the implemented GUI include the graphical icons and events controlled subroutines. Figure 1 illustrates the layout of the implemented GUI used for our image processing system. The 3-D buttons on upper right-hand is the main menu which lets users select the subroutines to be operated. All the codes for our GUI are written in C++ language, a superset of C language.

Image processing modules

As discussed by J. Lobel[11], the major steps in image processing are: image capture, segmentation, object detection, measuring and analysis. Routines for image capture have already been discussed in the previous section on interface modules. Usually, a multiple gray level image will be obtained from the operation of image capture step. The purpose of segmentation is to separate the interest object of the multiple gray level image from the background. Generally, a binary image containing white objects of interest and black background result from the segmentation operation. Various segmentation methods can be found in the literature,[12-14] and "thresholds" is one such method. The simplest form of thresholds is to select a specific gray level such that all of the pixels with an intensity below or above the selected value are set as black and white, respectively.

In practice, either mode of user interaction or an automatic histogram searching technique can be used to select the threshold value. Following segmentation, the object detection operation provides the ability to identify individual particle images. The seed filling[15] and edge detection[13] methods have been implemented to perform this function.

Measurement and analysis modules

Measurements allow for quantitative image information to be obtained. For this system, geometrical properties of the objects including the area, chord length, and perimeter are measured. The shape factor of an individual image as used in this study is defined as :

$$\textit{Shape factor} = \frac{4\pi\,(\textit{Area})}{(\textit{Perimeter})^2}$$

The analysis operation involves classification of the measured data.

ASH DEINKING FLOTATION TESTS

Air-sparged Hydrocyclone (ASH) deinking flotation for three typical wastepaper resources (newsprint, xerographic, and magazine) were carried out at the University of Utah. For each deinking flotation test two kilograms of wastepaper, 5 grams of sodium tripolyphosphate, 5 grams of sodium hydroxide, together with a suitable amount of promoter (emulsified oil to enhance deinking flotation), was first pulped with hot water (80 °C). The pulp was dispersed with a high-speed blender and then diluted to about 1% solids by weight with fresh cool water. The prepared pulp was then sampled for image analysis prior to ASH deinking flotation. Air-sparged hydrocyclone flotation was carried out with a 2-inch ASH system with addition of frother. The overflow product was waste ink reject and the underflow product was the clean fiber accept. After flotation, both waste reject and clean fiber accept samples were collected for particle characterization studies.

PARTICLE CHARACTERIZATION

Hand Sheet Samples

The hand sheets of waste reject and clean fiber accept for each wastepaper type as obtained from the ASH deinking flotation tests were prepared by filtration. The filtered sheets were naturally dried and taken for image analysis.

The typical illustrations of original images and segmented images of the pulp sheets as obtained from the ASH flotation tests for newsprint, magazine, and xerographic are given in Figures 2, 3, and 4, respectively. As can be seen from these images, both ink and fiber particles can clearly be identified for both xerographic and newsprint samples. Among the three wastepaper hand sheets the number of total ink particles in the pulp sheets was found to increase from newsprint to xerographic to magazine. Most ink particles were removed and concentrated into the waste rejects from the clean fiber accept products by ASH flotation. All the large ink-particle aggregates (>50 microns), promoted by the flotation schedule used, are found to be concentrated in the waste reject of ASH flotation for all three wastepaper types. Some fine ink particles (0-50 microns) still remain and are left in the clean fiber products after ASH flotation as seen from the original images.

With appropriate selection of bilevel segmentation, the segmented images provide clearer representatives of the various size/shape ink particles for all hand sheets. The original image of ink/fiber particles in the pulp sheets can be significantly enhanced and easily identified after segmentation. From the segmented images the information on the particle size (size based on the area of an equivalent circle), chord-length, and shape of all ink particles can easily be obtained, transferred, and stored using the PC computer (data processing system).

The size distribution of ink particles in the three hand sheets as obtained from their segmented images is presented in Figure 5. As seen from Figure 5 the ink particles vary in size from 0 to 100 microns. In all cases the ink particles were found to be most abundant in the 5x10 micron size class. A significant number of ink particles of all sizes were recovered into the waste reject by ASH flotation from the pulp suspension. With a single stage ASH flotation more than 90% of small-size ink particles (<50 microns) and all large-sized ink-particle aggregates (>50 micron) have been removed from the pulp suspension. It is evident that ASH flotation technology provides a high efficiency of removal of ink particles from the pulp suspension for all ink particles and wastepaper types, and is particularly effective for large size ink aggregates.

Pulp Suspensions

Three representative pulp suspensions (newsprint, xerographic, and magazine), as obtained from the preparation of flotation feed, were used for image analysis. The suspensions consisted of 1% wastepaper by weight. The pulp samples were placed into a glass vessel for the image analysis.

The original images and segmented images for all three pulp samples (newsprint, xerographic, and magazine) are given in Figure 6. In addition to black ink particles some white ink particles in magazine pulp and some trapped air bubbles in xerographic pulp are also observed from the images. The size distribution of ink particles as obtained from their segmented images for the three pulp suspensions is presented in Figure 7. The number of ink particles in the paper pulps as obtained from the segmented images is found to increase from newsprint to xerographic to magazine. All ink particles were found to be less than 60 microns in size.

The shape of the ink particles (>15 micron) in the pulps as observed from the segmented images were evaluated and the shape factor along with the standard deviation are presented in Table 1. As seen from Table 1 the shape factor of ink particles in the pulps is found to increase from magazine to newsprint to xerographic. In other words, the ink particles seem to be more round in shape for xerographic pulp and of a less round shape for magazine pulp with ink particles in the newsprint pulp of an intermediate shape (shape factor = 1 for a circle and less than one for all other shapes).

All the preliminary results indicate that the image analysis system has been quite successful for the evaluation of products obtained from ASH deinking flotation tests. The quantitative image analysis can give both the size and shape of ink particles for such products. It is evident from these original images and segmented images that our PC based image analysis system can be successfully employed to quickly analyze ink particles in hand sheets and in pulp suspensions in terms of particle size, chord-length, and shape for all wastepaper samples.

SUMMARY AND CONCLUSIONS

A low cost PC image-based particle analysis system is being developed for particle characterization of deinking hand sheets and paper pulps at the University of Utah. This PC based image analysis system can be successfully employed to quantitatively analyze ink particles in the pulp sheets and pulp suspensions in terms of particle size, chord-length, and shape for all wastepaper samples (newsprint, xerographic, and magazine). Preliminary results indicate that the system is quite successful for the evaluation of products obtained from deinking air-sparged hydrocyclone flotation tests.

On the basis of these results the potential of PC based image analysis system for the characterization of both hand sheets and pulp suspensions is evident. Based on these encouraging results, research should be continued to develop a PC image-based on-line instrumentation of such a system for the control of plant operation. In this regard, further research and development is warranted, and efforts are being made to initiate a dedicated R&D program.

ACKNOWLEDGMENTS

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Table 1. Shape factors of ink particles in pulp samples as obtained from segmented images

Wastepaper Pulps (1% wt.)	Shape Factor
Magazine	0.799 ± 0.171
Newsprint	0.865 ± 0.147
Xerographic	0.883 ± 0.127

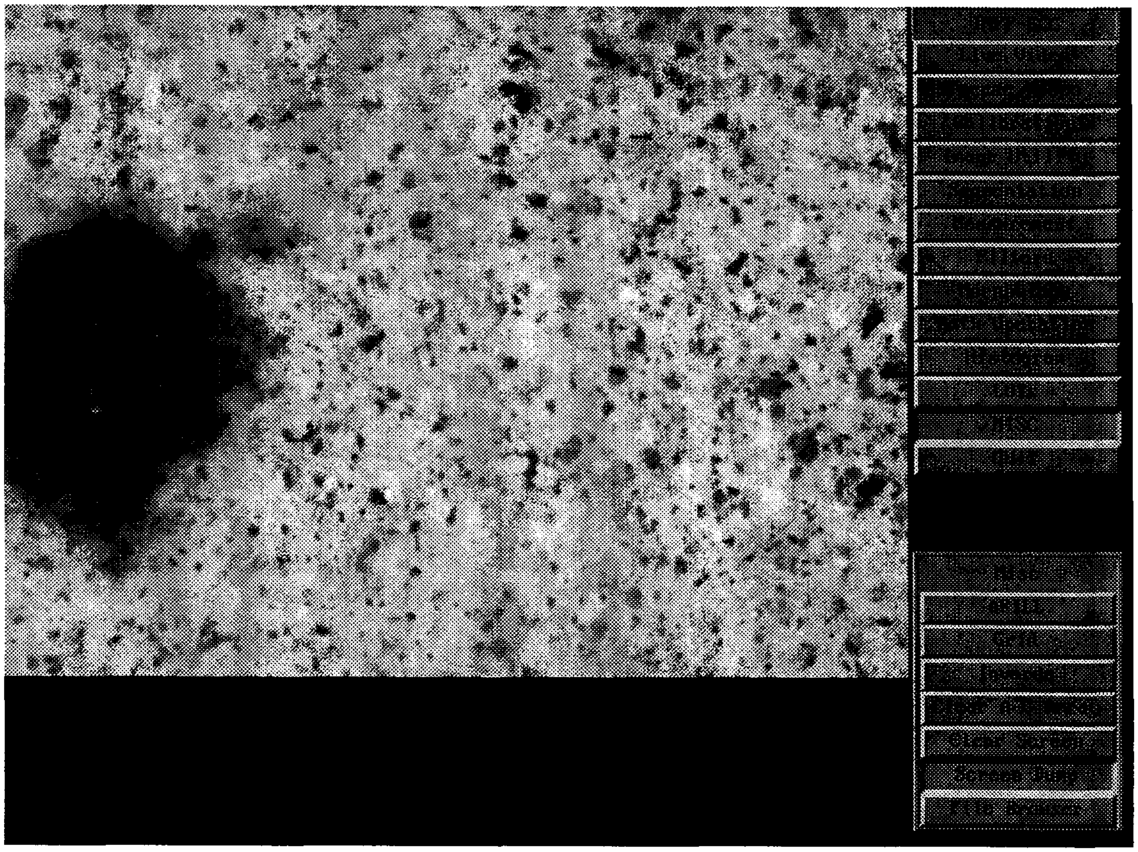
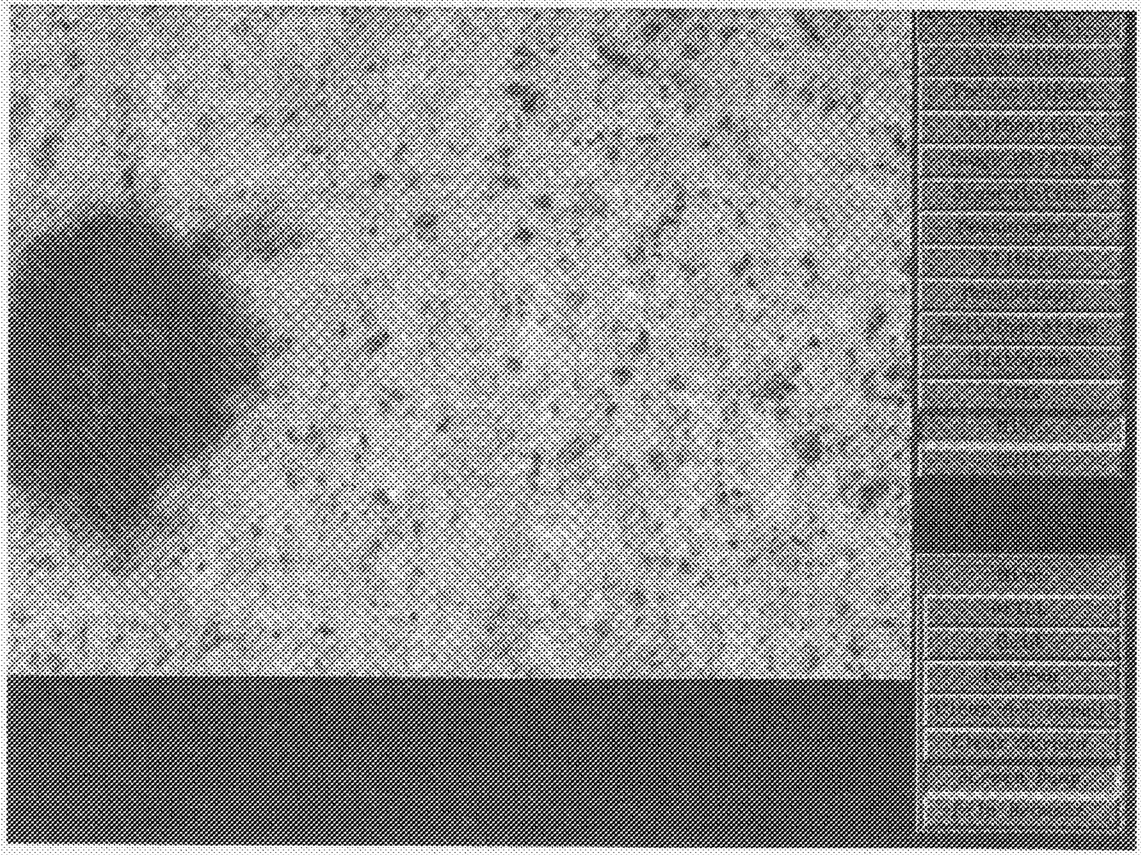


Figure 1. Layout of the graphical user interface (GUI) for the image-analysis system.



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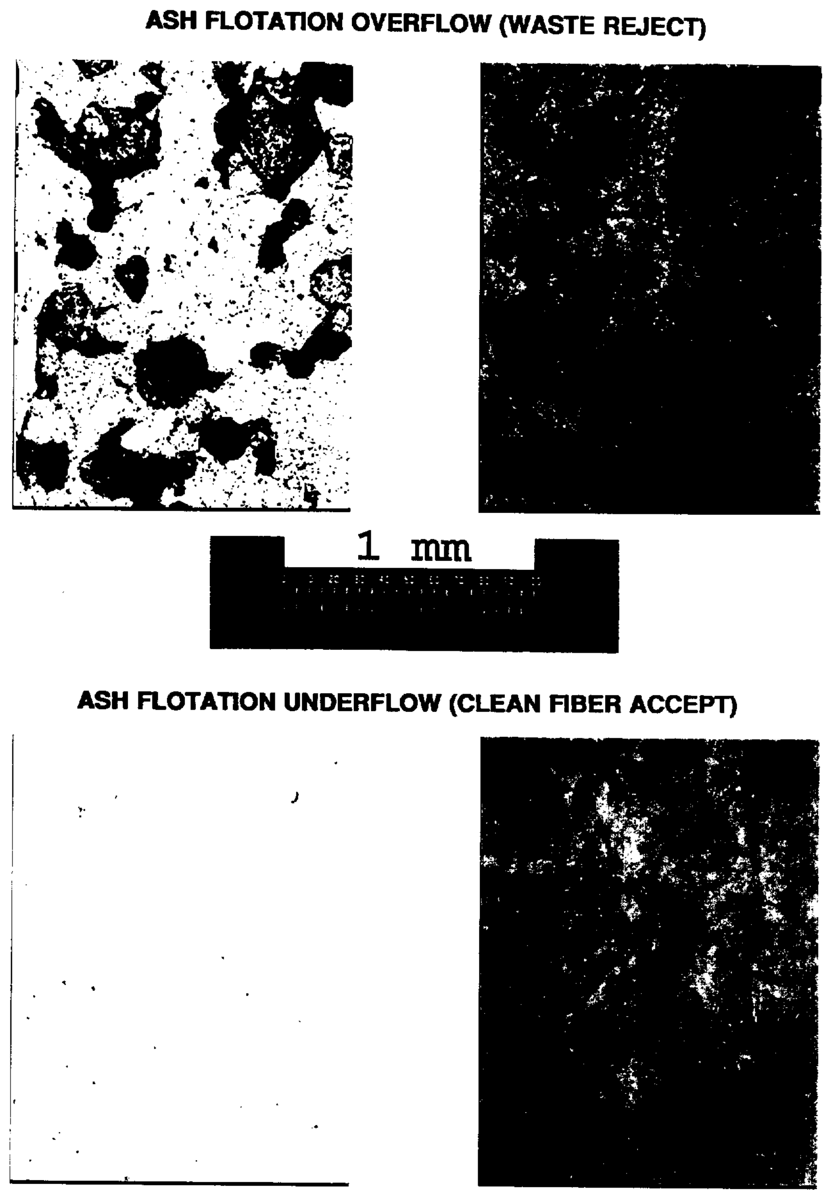


Figure 2. Illustrations of original image and segmented image of newsprint hand sheets as obtained from ASH flotation.

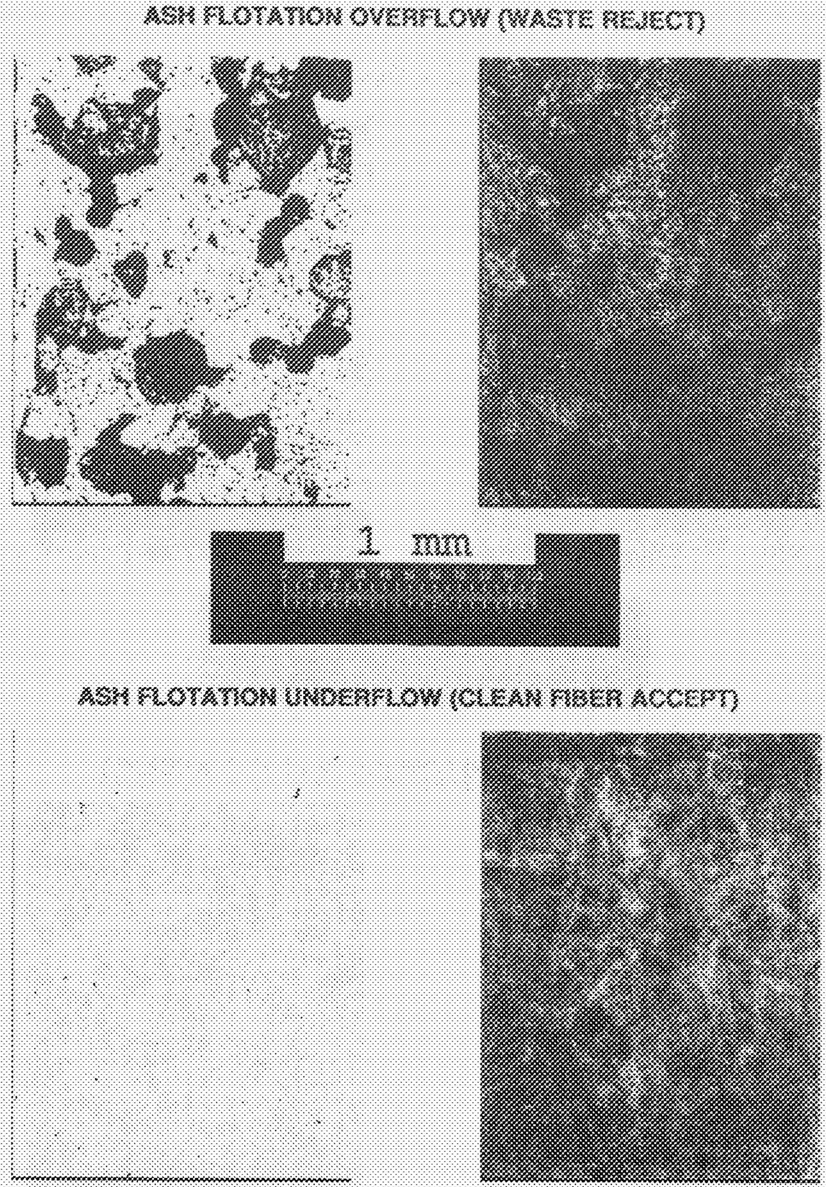


Figure 2. Illustrations of original image and segmented image of newsprint hand sheets as obtained from ASH flotation.

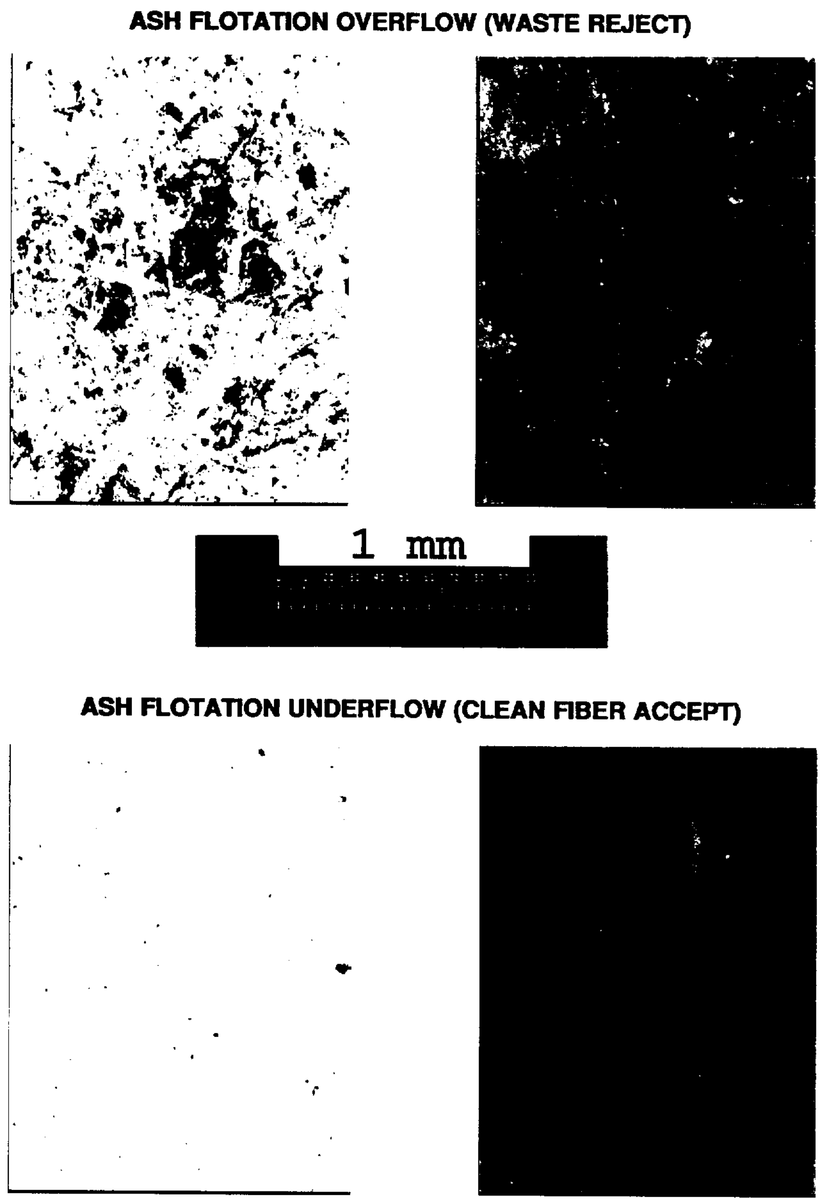


Figure 3. Illustrations of original image and segmented image of xerographic hand sheets as obtained from ASH flotation.

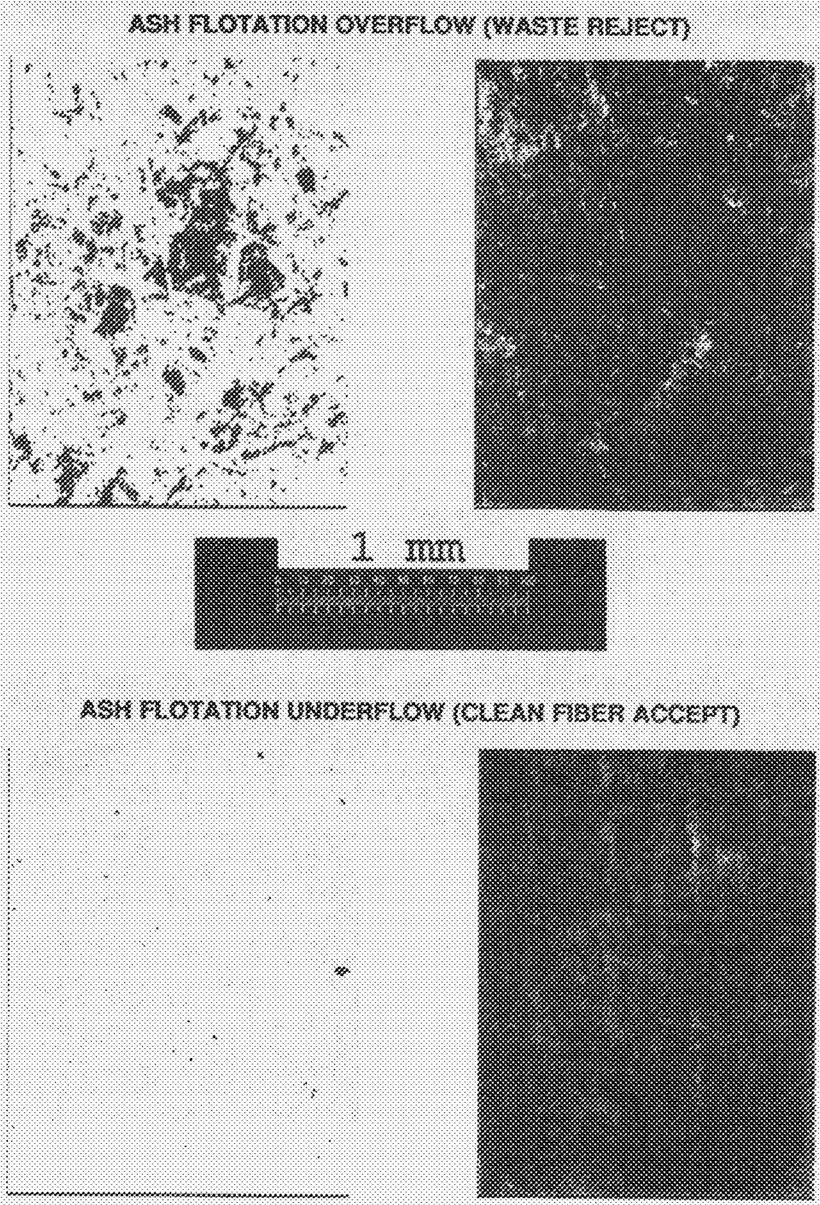


Figure 3. Illustrations of original image and segmented image of xerographic hand sheets as obtained from ASH flotation.

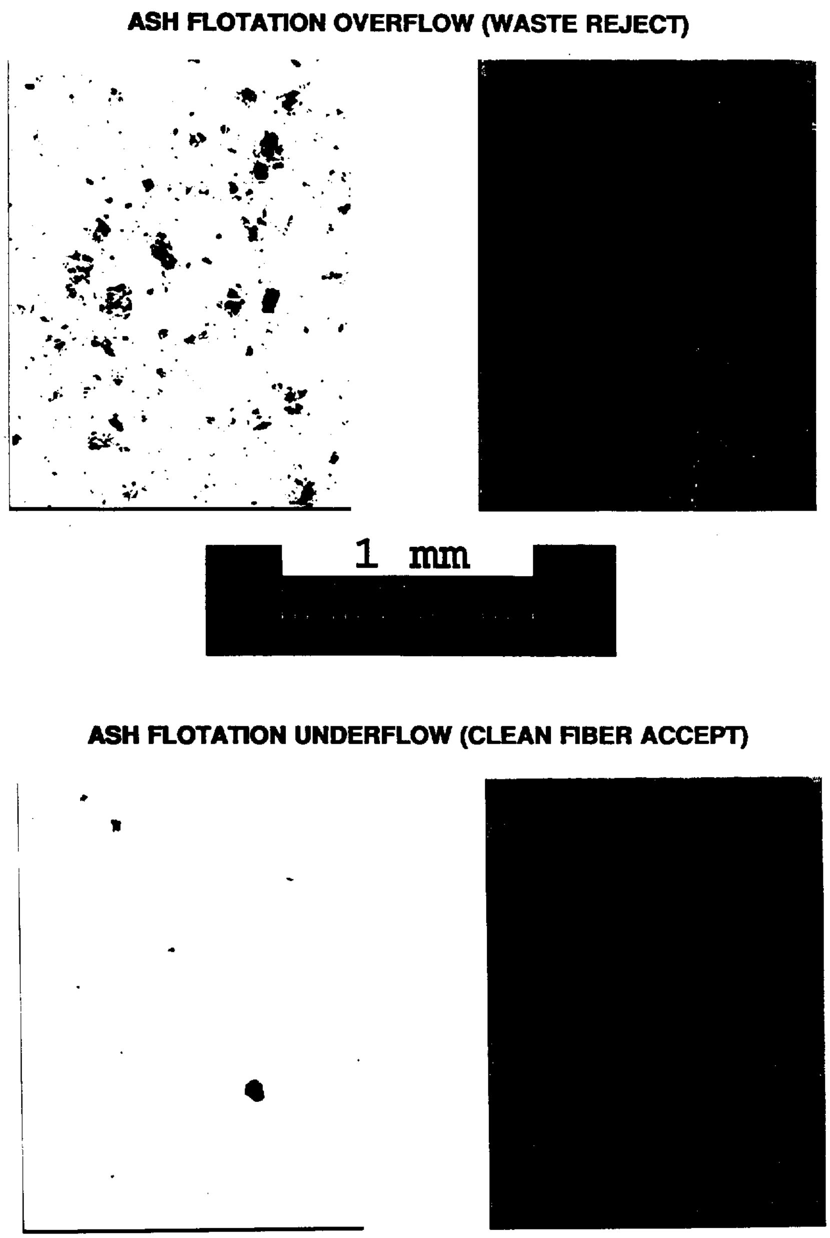


Figure 4. Illustrations of original image and segmented image of magazine hand sheets as obtained from ASH flotation.

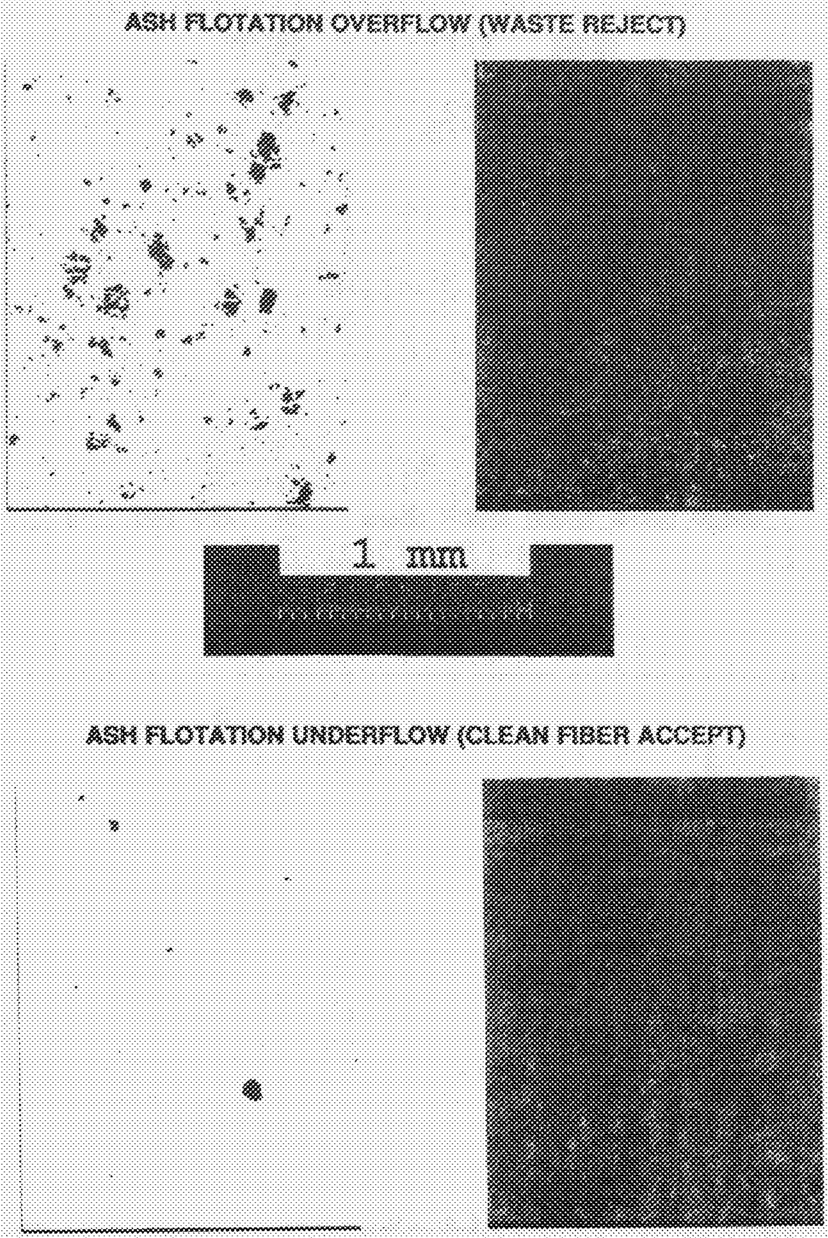
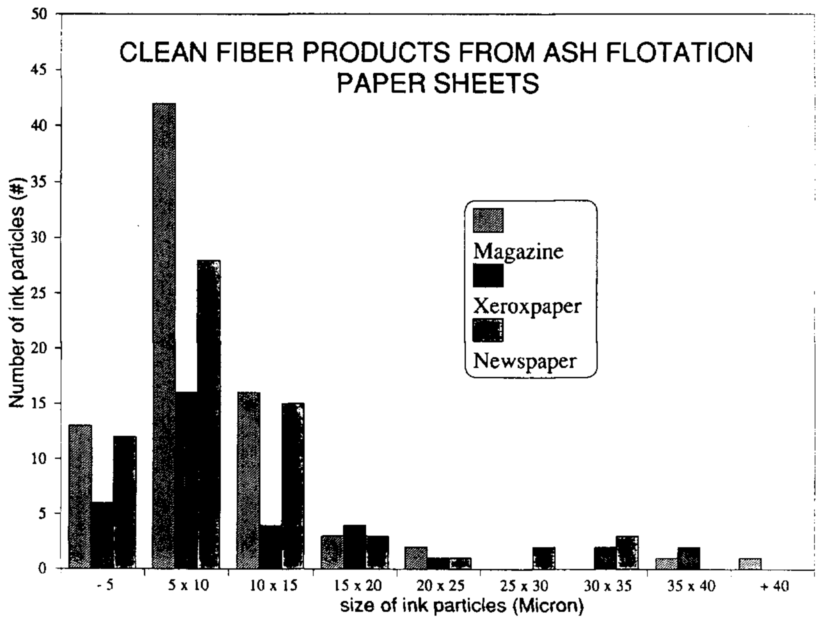


Figure 4. Illustrations of original image and segmented image of magazine hand sheets as obtained from ASH flotation.



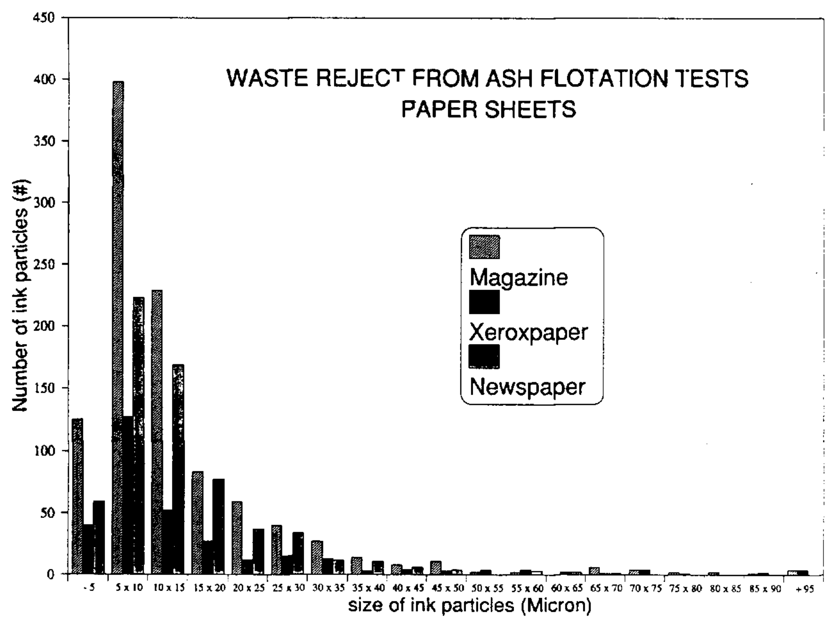


Figure 5. Size distribution of ink particles in the three hand sheets of ASH flotation products as obtained from the segmented images.

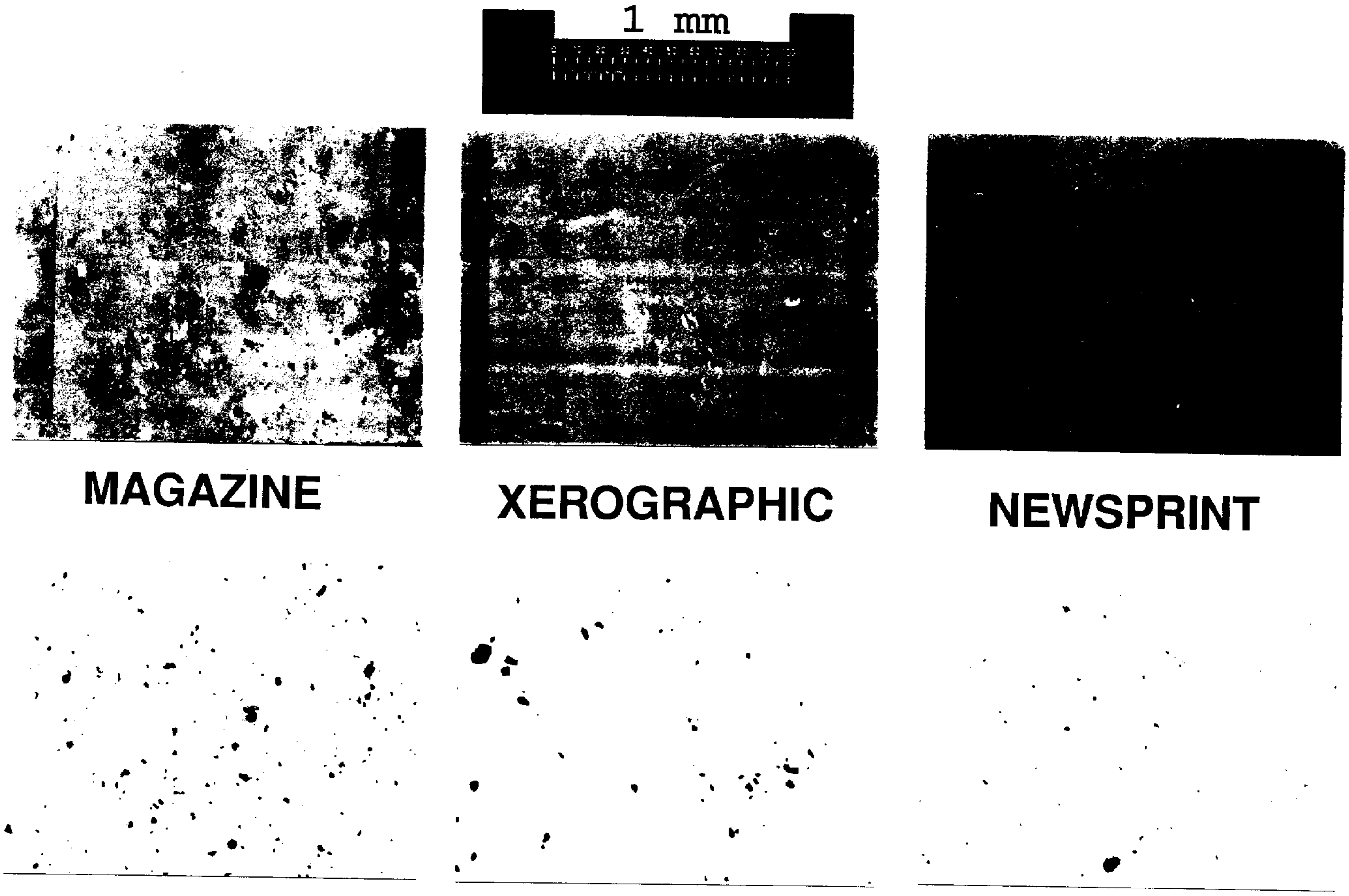


Figure 6. Illustrations of original image and segmented image of three pulp samples (newsprint, xerographic, and magazine)

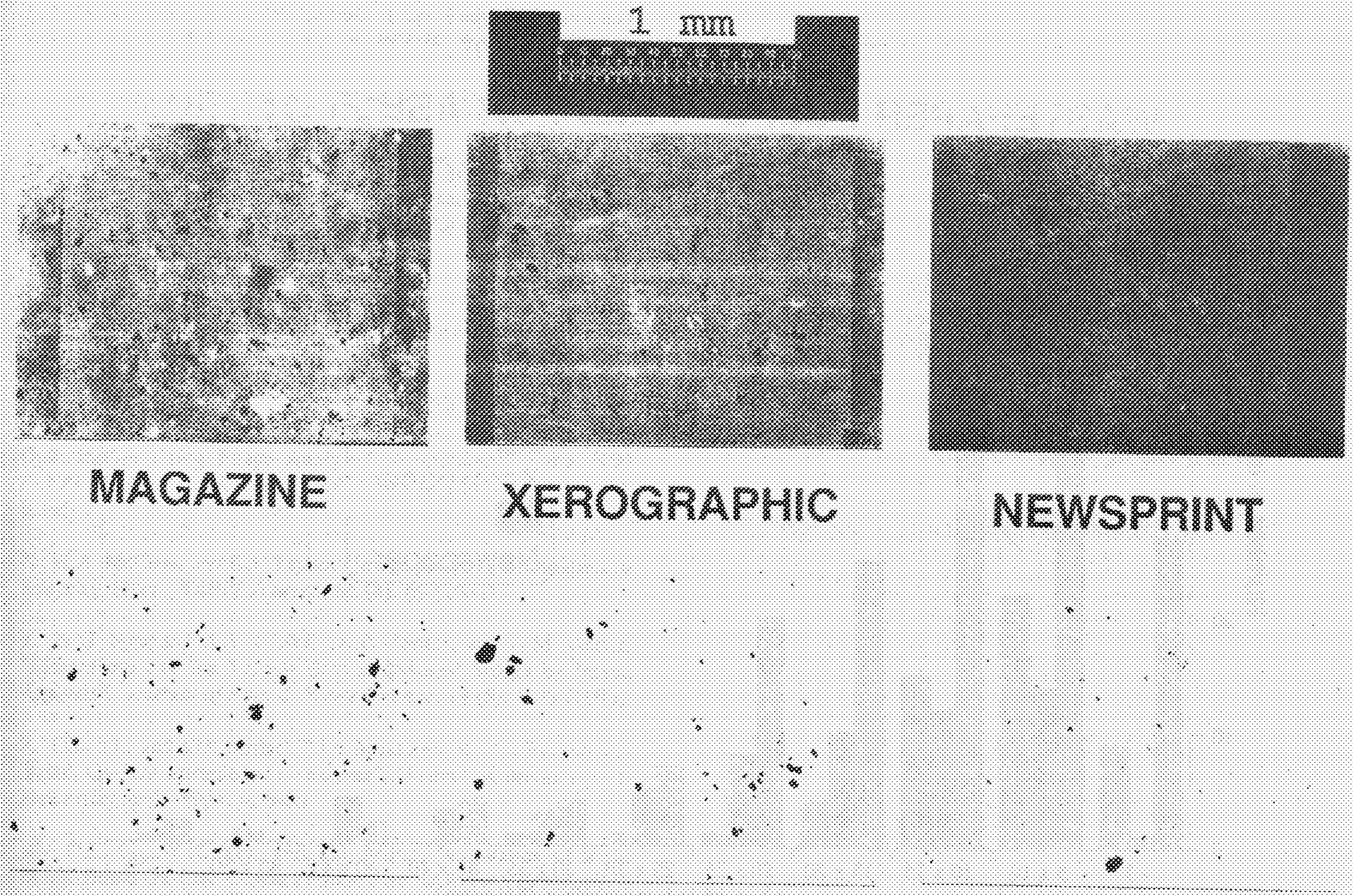


Figure 6. Illustrations of original image and segmented image of three pulp samples (newsprint, xerographic, and magazine)

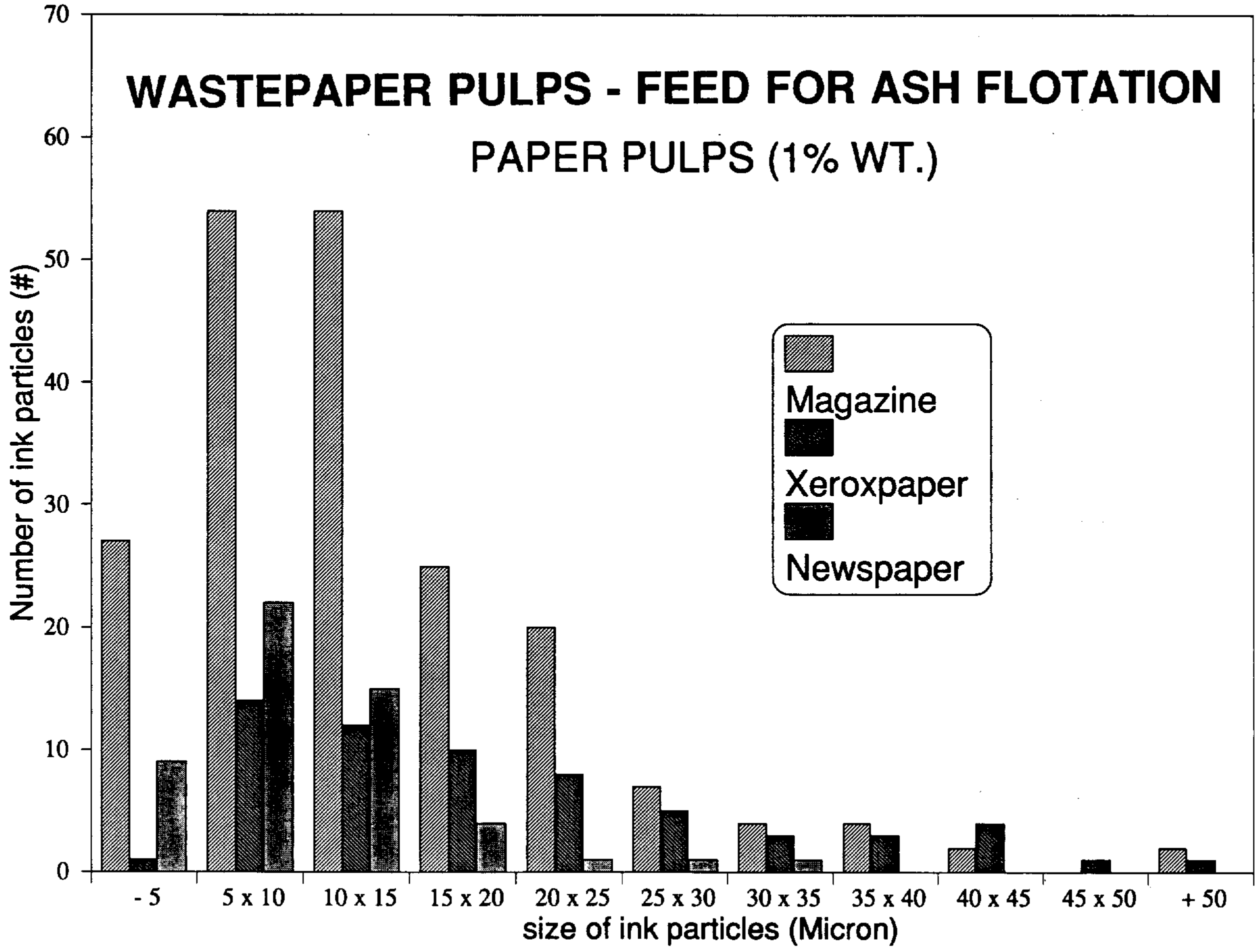


Figure 7. Size distribution of ink particles in the three pulp samples as obtained from their segmented images.

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