COMPUTER VISION IN MICROSTRUCTURAL ANALYSIS

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PREREQUISITE KNOWLEDGE: This material could be demonstrated to a high school level materials science student, but would be more useful to a student at the college freshman level or above. This experiment is intended to convey to the student that properties are a consequence of the microstructure and, therefore, characterization of microstructure is very important.

OBJECTIVES: To demonstrate that the microstructure of engineered materials is affected by the processing conditions in manufacture, and that it is possible to characterize the microstructure using image analysis with a computer.

EQUIPMENT AND SUPPLIES: 1) Laboratory heating or melting furnace, 2) molding sand and mold boxes, 3) aluminum-7% silicon alloy ingot, 4) stepped bar pattern, 5) chromel-alumel thermocouple and indicator, 6) metallographic sample preparation facility, 7) personal computer with accessories as detailed in the paper.

PROCEDURE: The principle of computer vision will first be introduced followed by the description of the system developed at Texas A&M University. This in turn will be followed by the description of the experiment to obtain differences in microstructure and the characterization of the microstructure using computer vision.

The phenomenal advances in the computer and microelectronics industry have made computer vision within the affordable range of budget strapped users. A decent system could be assembled for under $10,000 and the prices are still falling. In this paper, we will introduce one such system and its application in microstructural analysis.

The application of computer vision in microstructural analysis varies in degree of sophistication from simple determination of phase ratio, up to sophisticated grain size and morphology analysis. For the sake of simplicity, we will suffice with the introduction of phase ratio determination as a simple but effective method for introducing imaging analysis methods in material science laboratory education.

System Description:

The microcomputer image acquisition and analysis system used in this experiment consists of two main modules: the optical module, and the image and analysis module.

The optical module consists of a Nikon MeasureScope 20 microscope equipped with the proper optical elements and lighting fixture. The microscope was also fitted with a lightweight black and white CCD (coupled charged device) camera. Depending on the specimen to be studied, the proper magnification and lighting method could be determined by trial and error.

The image acquisition and analysis module is based around a 10 MHz AT-compatible 286 microcomputer, 1 Mbyte random access memory, and 40 Mbyte hard disk. A color monitor is optional. The computer is equipped with a (PCVISION) frame grabber and image analysis board. This board is capable of storing 2 images with a 512x512 resolution, in addition to the capability of on-board image manipulation. The captured and processed images are displayed on a B&W TV monitor connected to the image board.

The control and analysis software runs under DOS (disk operating system) and is composed of two different components. First, a menu driven software component is used to grab, filter, and perform some basic measurements on the images, and finally store them in the image data base. With the system also comes a subroutine library containing functions that ease the manipulation of images. Using those subroutines, the user can construct functions tailored specifically for a particular application.

A typical digital image is composed of a collection of image elements, each known as a pixel, which represents the average light intensity over a discrete portion of the total image. Both spatial resolution and light intensity resolution of the image depend on the hardware used, but a 512x512 pixel image with 256 gray level represents an average reasonably priced system.

Phase Determination Procedure:

As a first step, a digitized image of the specimen in question needs to be acquired by the computer. This could be obtained directly through the camera mounted on the microscope from a metallographically prepared specimen. If a direct image is not feasible, a digitized image could be obtained from a still photograph scanned through a digitizer. It is very important in both options to preserve the contrast between the different phases in question. Weak contrast between the different phases will increases the difficulty of subsequent phase discrimination steps.

To obtain phase discrimination in the image, it is crucial to map each phase in a different gray level intensity zone. Under ideal conditions, and if the contrast in the original image is good, a simple transformation of the image to a binary black and white by simple thresholding will suffice, see Figure 1. Thresholding is a simple operation whereby pixels with a value above a preset threshold are assigned a binary value of 1 (or white). If a pixel's intensity value is below the threshold it is assigned a value of 0 (or black), as shown in Figure 2.

In many cases, the image quality is not superior, or contrast between the phases in weak. In such cases, a number of alternatives can be used to improve the quality of the picture. In conditions where the images are noisy, a number of filtering methods could be used to obtain a better separation between the phases in the image. Such filters include convolution operators like smoothing, sharpening, or averaging filters. Other filters include morphological filters like dilation and erosion operators. The majority of those filters are included as part of basic image processing package.

Even in cases where phase discrimination exists but with minimal difference in the intensity, area measurements become sensitive to the choice of a cutoff threshold value. In such situations a method called histogram stretching is used to enhance the contrast as shown in Figure 1.

In the case of a binary phase material where a thresholded binary image is obtained, phase fraction determination can be obtained by calculating the fractions of black and white areas. A simple program that tests the image pixel by pixel keeping account of pixel count, then calculating the fraction will perform this task.

Experiment Example:

An experiment to determine the effect of section thickness (cooling or solidification rate) on microstructure of Al-7%Si was performed by senior level undergraduate students at Texas A&M University.

A stepped bar pattern was used to make a composite casting of different thicknesses. The cooling curve in each section of the stepped bar, as the casting solidified, was recorded using a chromel-alumel thermocouple connected to a digital temperature readout. In Figure 3 the cooling curves thus obtained are shown. Each section of the casting was then metallographically polished and etched to reveal the microstructure. The percentage of alpha phase in each section was then determined using the image analysis procedure described earlier and was plotted against the casting thickness, as shown in Figure 4. It is seen that the percentage alpha decreases with increase in section thickness (or decrease in cooling rate). This implies that the amount of eutectic (in the interdendritic regions of alpha) follows the reverse trend. Since the eutectic contains brittle beta phase, it follows that the strength of the aluminum-7% silicon casting decreases with increase in section thickness. In Figure 5 is shown a typical photomicrograph with alpha (white) and alpha plus beta(dark) phases. The percentage alpha measured by the lineal analysis method for this case was about 65%, which compares favorably with the value of 67.5 % shown in Figure 4.

REFERENCE: Flemings, M.C., Solidification Processing, McGraw-Hill, 1974, pp 134-172.

SOURCES OF SUPPLIES: The casting materials, equipment and supplies can be obtained from companies listed in the Thomas Register. The personal computer (PC-AT) can be purchased from any reliable source. For details of the image analysis system, please contact the authors.

CONCLUDING REMARKS: The casting experiment has been chosen merely to demonstrate the need and capability to characterize the microstructure. Image analysis can be useful for any engineered product, manufactured by processes like forging, rolling, welding, etc.

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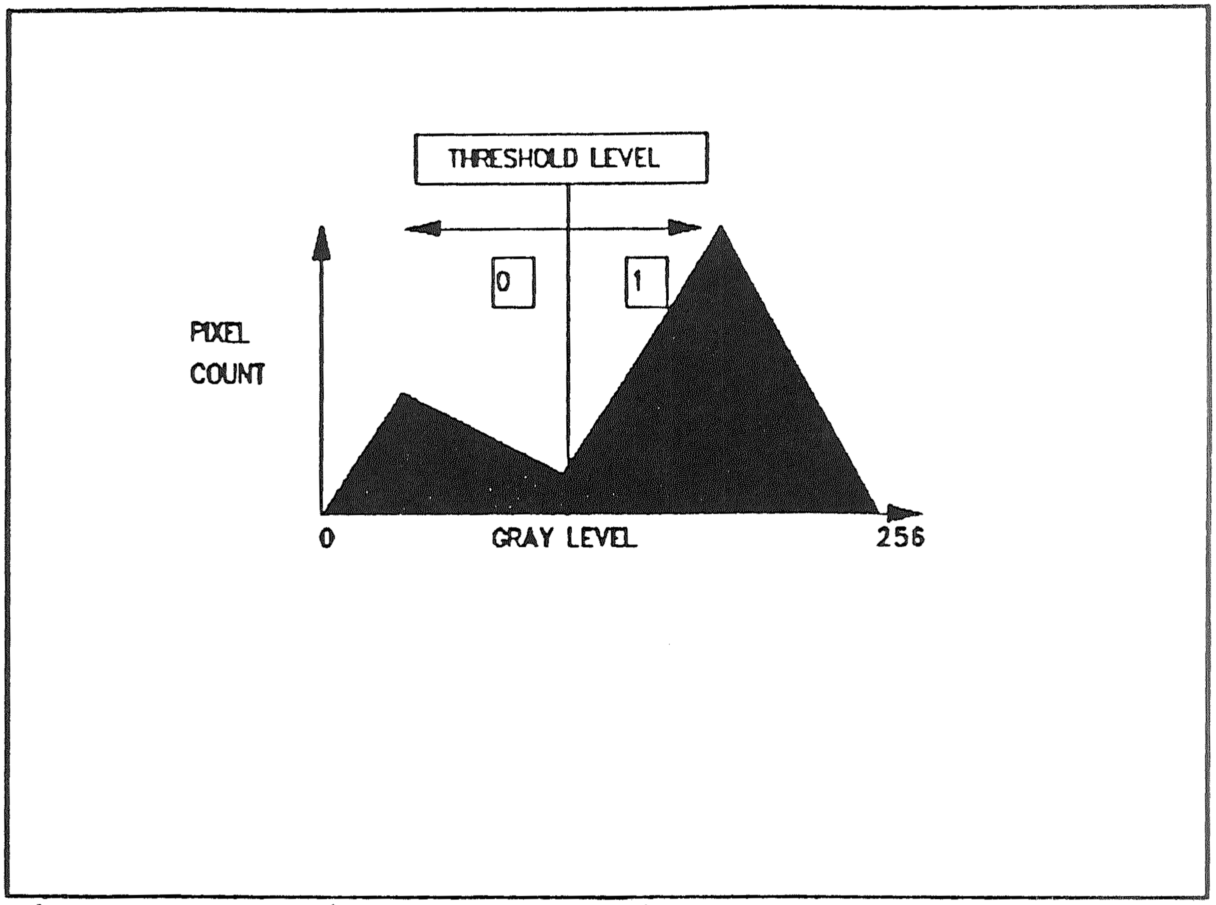

Figure 1 Image histogram stretching

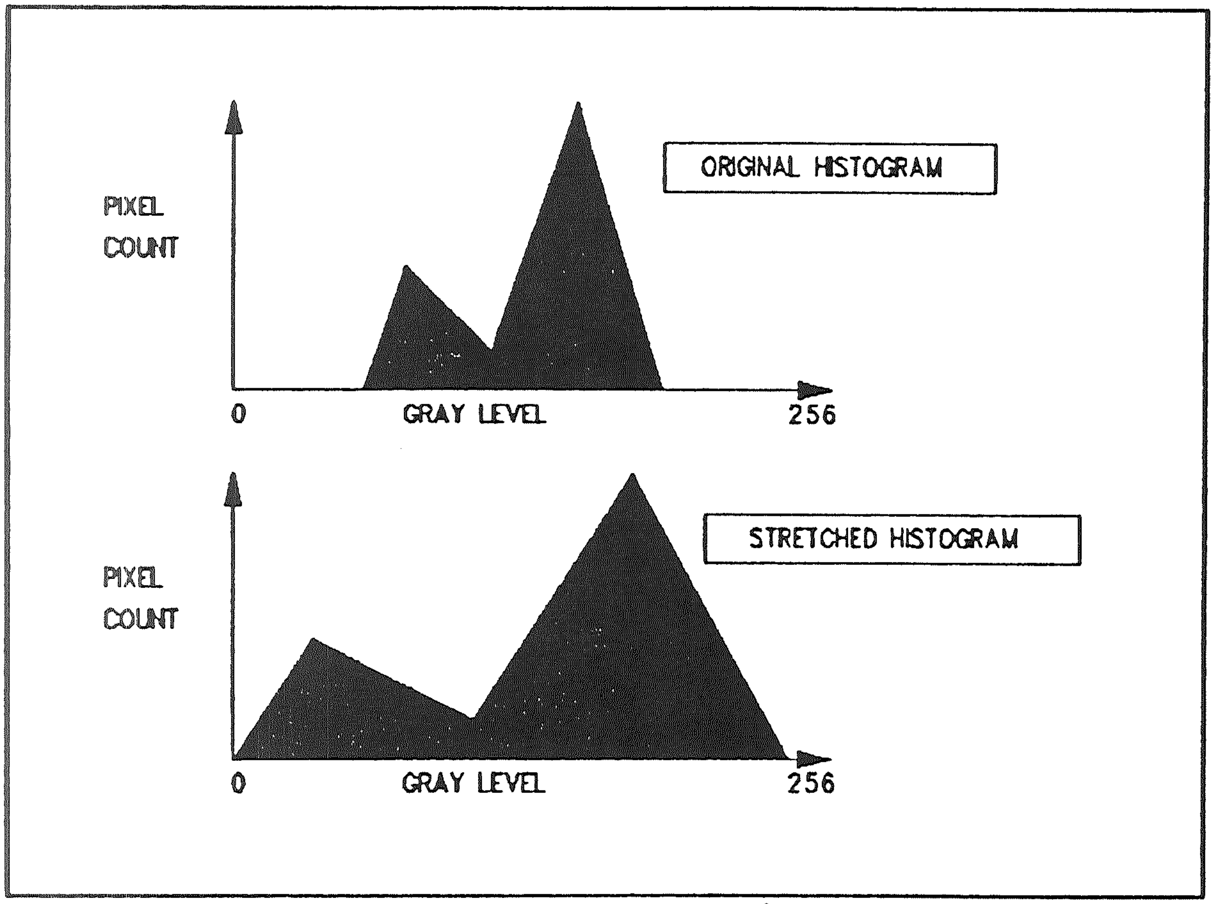

Figure 2 Threshold selection in image histogram.

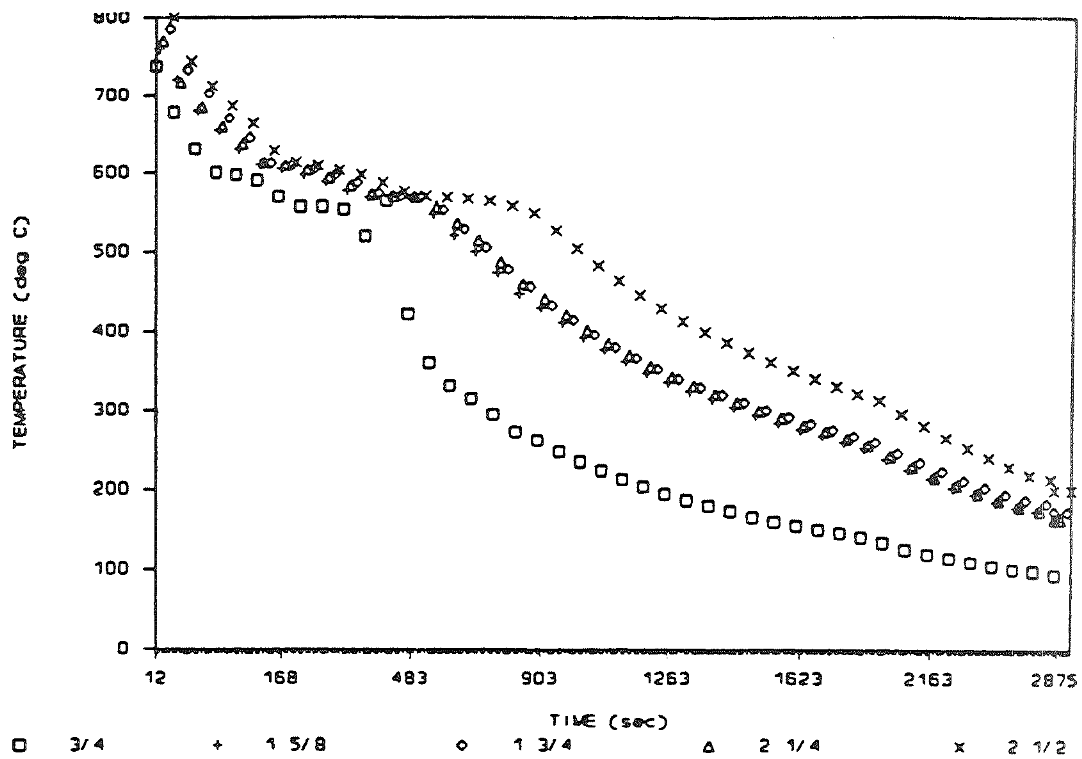

Figure 3 Casting cooling curves

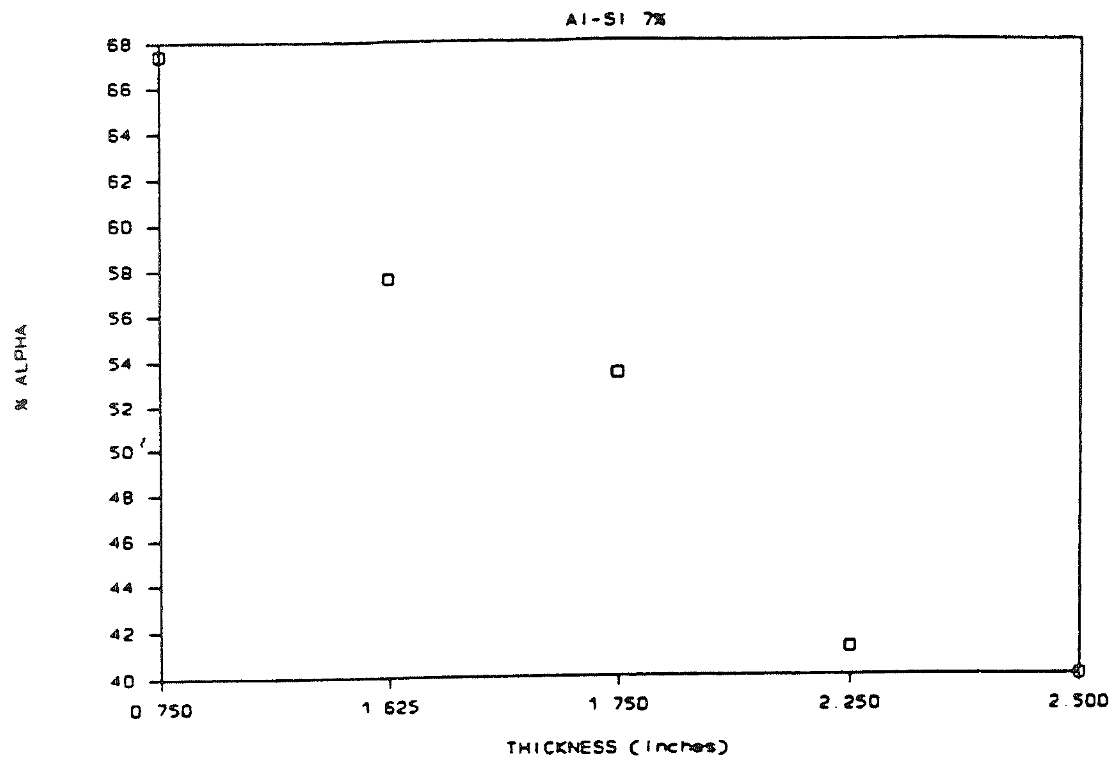

Figure 4 Percentage alpha versus section thickness

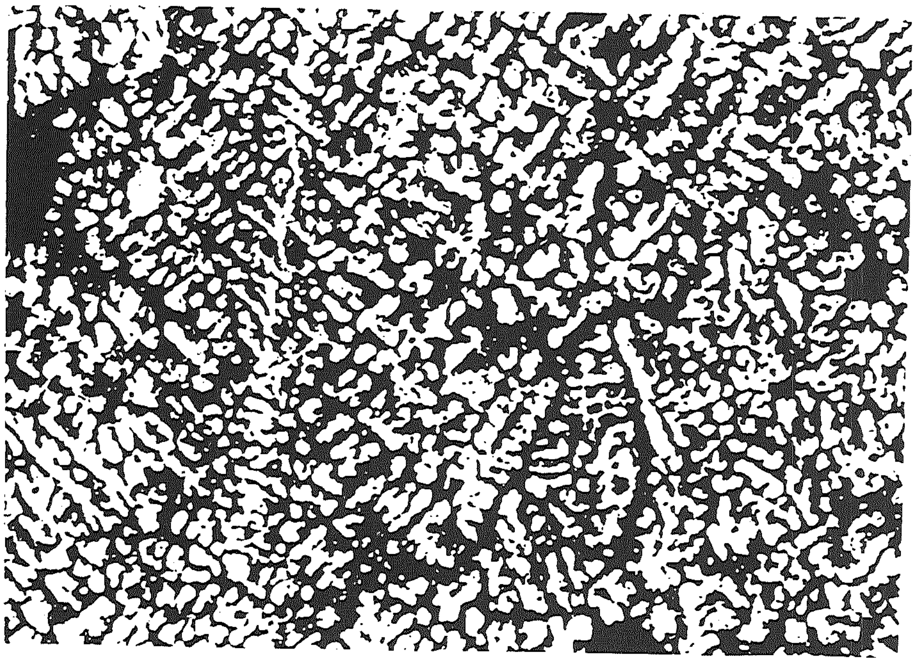

Figure 5 Typical microstructure of Al-7% Si casting