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A FILM COPYING TECHNIQUE FOR IMPROVING RADIOGRAPHIC CONTRAST*

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ABSTRACT

By copying radiographs on high gamma photographic film, a significant increase in overall system gamma can be obtained. For a given material of uniform density, a change in thickness will result in a change in X-ray transmission which in turn produces a change in the optical density of a radiograph. This change in density can be intensified by factors as high as 6 times by film copying techniques. A number of applications, in which this intensification has proved useful, are described.

INTRODUCTION

The reproduction of radiographs for slides, exhibits, reports and similar purposes is something that is frequently required. The techniques which can be used for reproductions of this nature are covered in numerous publications; a few of these[1-3] are listed in the references given. In general, the requirement for such reproduction methods is that the reproduced image should preserve as closely as possible the tonal range of the original radiograph. Other reproduction and intensification techniques which have been described in the literature include those which can be used to assist in visualizing small detail by the employment of photographic enlargement[4] and to intensify underexposed radiographs by chemical toning methods.[5,6]

The technique described in this paper differs from these other methods in that the purpose of this reproduction method is to intensify the contrast. The method can be used successfully with radiographs of almost any reasonable optical density.

DESCRIPTION OF THE METHOD

A. Theoretical

To accomplish this improved contrast, the original radiograph is copied by conventional methods on a high gamma photographic film such as Kodak Contrast Process Ortho or Panchromatic film. By taking advantage of the high gamma of these films, the density differences on the original radiograph can be intensified by factors in the order of 6 times. The intensification process can be demonstrated by referring to Fig. 1, which is a graphical representation similar to that described by Jones.(7)

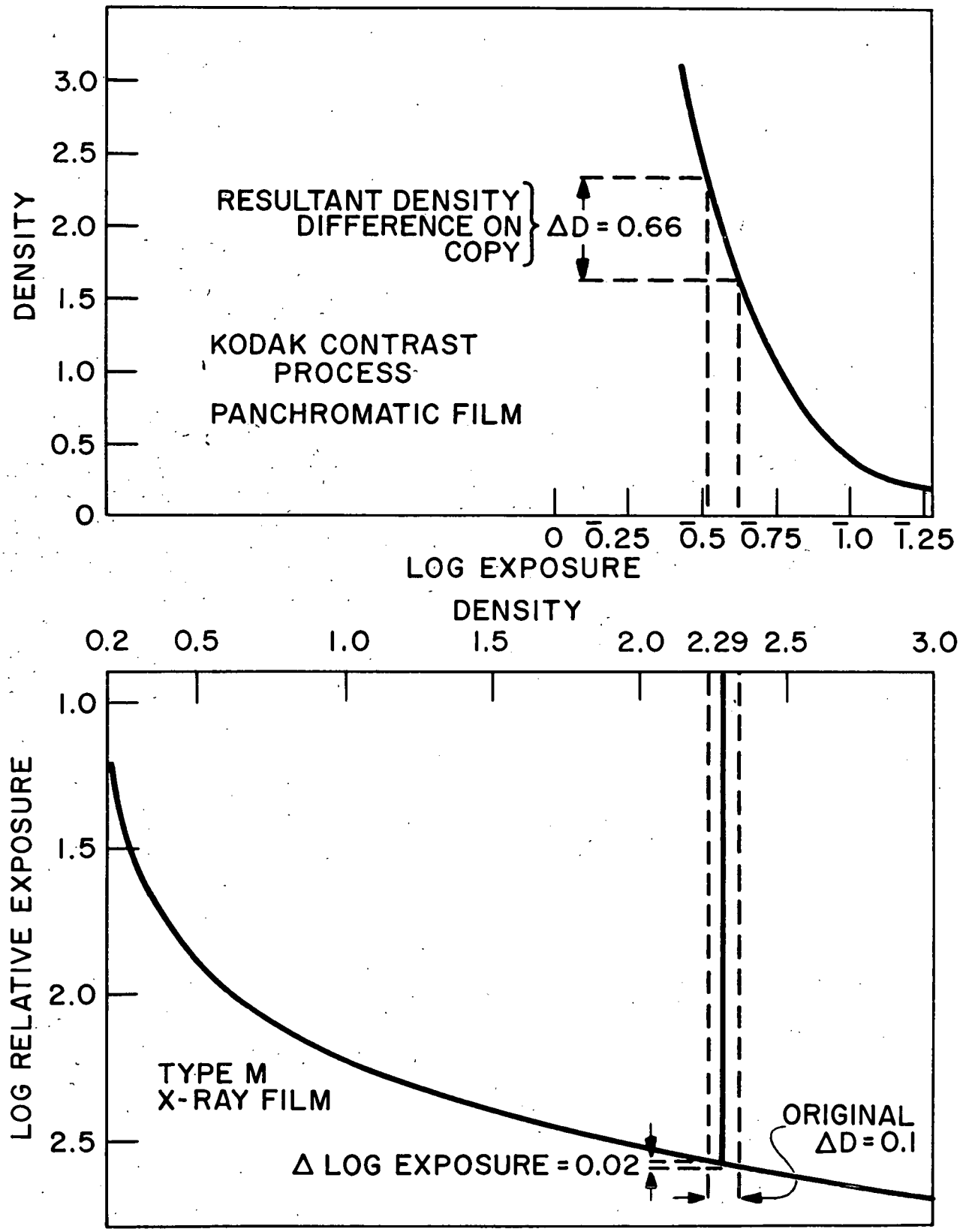
The lower portion of Fig. 1 is a plot of the characteristic curve for Kodak Type M X-ray film.(8) The upper curve shows the characteristic curve of Kodak Contrast Process Panchromatic film.(9) Note that the density scale for the X-ray film characteristic curve is plotted on the same axis as the log exposure scale for the copy film.

The scales are equivalent because, in the process of copying the X-ray film, the exposure to the copy film is determined by the opacity of the X-ray film and is inversely proportional to it. Since photographic density is defined as the logarithm of the opacity, the graphical analysis as shown in Fig. 1 is possible.

Actually, the characteristic of the light film can be shifted either to the left or right on this graph, depending upon the intensity of the light used to expose the light film and the time of exposure. Therefore, any portion of the X-ray characteristic curve can be copied with this film by varying the copy exposure conditions. Examples of this are given in the next section of this report.

FIGURE 1

CONTRAST ENHANCEMENT BY COPYING A RADIOGRAPH



If we further examine Fig. 1, it can be seen that a density difference (ΔD) of 0.1 on the type M X-ray film centered around a density of 2.29 (i.e. ΔD equals 2.34 - 2.24) can be intensified to a density difference of 0.66 in the copy film. The overall system gamma at that point is then a combination of the gamma of the X-ray film and of the copy film. At a density of 2.29, the gamma of type M X-ray film[10] is approximately 5.0. The overall system gamma using the copy film method would then be 5 x 6.6 = 33.0.

Let us summarize what we have just accomplished for this particular example. With an X-ray intensity change of about 5%, the corresponding log relative exposure is 0.02 and yields on type M X-ray film a density difference of 0.1 at a gamma of 5. When this difference is copied, a density difference of about 0.66 is obtained on the copy film, and we obtain an overall gamma of 33.[a]

In this example, the intensification of the copy method is a factor of 6.6. Using optimum techniques, the gamma of Kodak Contrast Process Panchromatic film can be increased[9] to about 6.8. Combining this with a gamma[10] of 7.5 for type M X-ray film at a density of 4.0, an overall system gamma of about 50 should be possible.

B. Experimental

The production of copy positives of radiographs for contrast enhancement can be done with equipment such as a contact printer or photographic enlarger. Some typical results of the range of densities which can be conveniently handled on a given copy positive are shown in Table I. The copies used for the data

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[a] The film gradient, gamma, is defined in reference 10 as the change in density divided by the change in log relative exposure over a given interval.

TABLE I

DENSITIES OF COPY NEGATIVES FOR

SEVERAL EXPOSURE CONDITIONS

Original Film Density	COPY FILM DENSITIES			
	Exposure 1	Exposure 2	Exposure 3	Exposure 4
0.06	3.9	4.60		
0.19	3.34	4.29		
0.34	2.72	4.14		
0.50	2.12	3.88		
0.65	1.58	3.48		
0.79	1.09	3.04		
0.93	0.64	2.56	4.13	4.85
1.07	0.32	2.02	3.96	4.76
1.23	0.15	1.48	3.62	4.59
1.38		1.00	3.17	4.44
1.55		0.58	2.67	4.21
1.70		0.28	2.03	3.94
1.84		0.14	1.46	3.58
1.99			0.86	3.04
2.13			0.46	2.52
2.29			0.22	2.00
2.45			0.10	1.42
2.60				0.92
2.75				0.54
2.88				0.28
3.02				0.14

in Table I were prepared on Kodak Contrast Process Ortho film using a contact printer. The object used to prepare the copies was a reference film step wedge of the type normally used with a densitometer.

If the density differences on the copy films are examined and compared to the density differences on the original film, a maximum gamma of approximately 4 will be observed for the copy film results. The orthochromatic film used for Table I is a lower gamma film than the panchromatic film[9] used in Fig. 1. Because of the lower gamma, however, the orthochromatic film copy method has somewhat more latitude. Again examining Table I, it can be observed that a density difference in the order of 1.0 on the original film yields a copy film spanning most of the useful visual range of densities. The maximum gamma portion of the copy film is even further limited to an original film density difference of approximately 0.5.

As far as the quality of the copy film is concerned, our experience indicates that the image sharpness obtained with equipment containing a single light source and lenses is better than when a typical contact printer is used. However, the difference is small and very useful copies can be prepared with contact printers.

Whatever copying equipment is chosen, it is suggested that data such as that given in Table I be prepared. In this manner, the correct exposure required to obtain a high gamma copy film of a given density range can be determined. Then any radiograph, or portion thereof, can be copied with confidence that a useful copy will be produced.

APPLICATIONS

The copy technique described is most useful for copying radiographs containing a small range of densities. Therefore, copy techniques used with

radiographs of castings or other more or less uniform thickness materials can be very helpful. In the inspection problems encountered at Argonne, the inspection of reactor fuel elements falls within this category. One specific case was the improved visualization of fuel homogeneity in reactor fuel plates. Copy methods have permitted relatively easy visualization of faults which were difficult to detect on the original radiographs. Although copy techniques are not routinely used, the availability of this technique for questionable cases has proved valuable.

Uniform density radiographs are not the only cases which lend themselves to copy techniques. For example, a portion of a radiograph which pictures a particularly critical area of an inspected part can be copied and examined for the density of particular interest. An example of such an inspection problem encountered at Argonne in which copy techniques were useful was the examination of EBR-II fuel rods. These rods contained sodium to obtain good thermal conductivity between the uranium and other portions of the fuel tube. With conventional radiographs, it was difficult to detect the level of the sodium within the assembly due to very small density differences. Copies have made it much easier to visualize this relatively low contrast area, even though it was in an area of the radiograph containing many relatively different densities.

CONCLUSIONS

The copying method described can be employed to appreciably increase the visibility of relatively low contrast areas on conventional radiographs. This improved system gamma is gained primarily at the expense of latitude in that only a relatively small range of densities can be copied on any one copy negative. Another characteristic of this technique which may present some problems to the film reader accustomed to conventional radiographs is that the copy is a positive compared to the original radiograph.

In spite of these minor disadvantages, however, it is our opinion that the technique is very useful and can be employed to make easily visible, density changes which may be marginal on the original radiograph. Although it is not claimed that the use of copy films results in improved contrast sensitivity,[b] the improved visibility of test pieces or flaws having low contrast on the original radiograph does help remove doubt in questionable cases.

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[b]The radiographs on which these tests were made yielded contrast sensitivities in the order of 0.2% as determined by experienced observers. Although copy films helped in the detection of images just on the threshold of visibility, the concensus of opinion was that sensitivity improvements were not obtained. In other words, no images were made visible on the copy film that could not be detected by experienced viewers on the original.

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