TECHNICAL NOTE

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On the Application of Metallurgical Techniques to Forensic Sciences

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ABSTRACT: Metallurgical techniques, such as metallographic examination, are seldom reported as being used in forensic science investigations. In these cases, most findings related to the metal's nature rely on visual and chemical examinations. The potential of applying metallurgical techniques to forensic science investigations is illustrated by means of two case histories. The information needed to establish a link between different pieces of metal is obtained from a metallographic examination of the metal's microstructure which reflects its thermomechanical history. It is shown that this kind of information is unique and cannot be obtained by applying conventional techniques such as chemical analysis. It is therefore concluded that metallurgical techniques can successfully complement other scientific techniques commonly employed in the forensic science context.

KEYWORDS: criminalistics, forensic science, metallurgical analysis. metals

The forensic sciences include a large number of diversified scientific and humanistic fields whose cooperation results in identification and clarification of facts which are often involved in criminal background. Among the engineering techniques employed are mechanical and chemical ones. However, surprisingly little attention has been paid by researchers and investigators to the field of metallurgy and its potential applications to the forensic sciences. As an example, the investigation of post-explosion debris involves in most cases dealing with metallic fragments. However, metallurgical techniques such as metallographic examination are seldom used compared to visual inspection [*1,2*]. Metallographic examination of the fragments microstructure is likely to provide (through specific deformation markings such as adiabatic shear bands) complementary insight on the strain rates involved, and may therefore yield information related to the distance between the investigated metal and the explosive [*3,4*].

Additional metallurgical techniques such as those currently employed in failure analysis of materials systems can be successfully applied in the investigation of forensic science cases. Some of these techniques will be briefly outlined [*5,6*].

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Extensive Visual Examination

The purpose of visual examination is to detect and ascertain the presence and origins of characteristic signs (for example, scratches, tool markings) on the investigated object.

Metallographic Examination

Metallographic examination is used to study the microstructure of the investigated material which is related to its thermomechanical history (for example, quenched and tempered, forged).

Fracture Surface Examination

The fracture surface is examined to identify the operating fracture mechanism (for example, fatigue, overload, and so forth).

Numerous other techniques are used, but those listed above are among the most useful and provide in most cases sufficient information.

The purpose of this paper is to illustrate, by means of two case histories, how metallurgical techniques—such as metallographic examination—that do not require extensive laboratory equipment, can be successfully applied to forensic science investigation.

Case Histories

Case 1: Metallic Bar Used as a Weapon

A metallic bar, approximately 30 cm in length and having a rectangular cross section, was found at a murder scene. Fingerprints, bloodstains, hair, and cutting marks were found on the bar. Fingerprint examination was rendered difficult because of the bloodstains which masked them. Upon searching the suspect's home, another metallic bar was found bearing cutting marks similar in aspect and geometry, and a need arose to establish a correlation between the two bars. Cutting marks were compared on the two cross sections, and it was concluded that both bars had been cut with the same type of disk saw. Additional information was gathered by comparing the chemical composition of the two bars. Energy dispersive X-ray analysis results showed that both materials contained mainly iron (along with traces of chromium, manganese, nickel, and copper) without any major alloying elements.

Metallographic examination was carried out on samples taken from matching sections in the bars. The microstructure typical of both the investigated materials was found to be predominantly ferritic with minute quantities of pearlite, which is characteristic of low carbon hypoeutectoid steels (Fig. 1). Grains were equiaxed and of an average size of 20 μm in both cases, and slight banding of the pearlitic colonies was observed. Hardness measurements indicated that both materials were of hardness levels of 20 to 22 HRC (Rockwell C).

The metallurgical examination revealed a high degree of similarity between the material of the bar used as a weapon and this of the bar found at the suspect's home. These results increased the probability that the two objects were sawn from the same bar.

Case 2: Pistol Magazine

During an investigation of a criminal case involving the use of a semiautomatic pistol, the cartridge magazine drew special attention from the investigators. This magazine was obviously not the original magazine furnished with the pistol, but had rather been fabricated from a metallic sheet by a skilled amateur (Fig. 2). Upon searching the suspect's apartment, a metal sheet similar to the magazine's sheet was found. It was also noted that both sheets

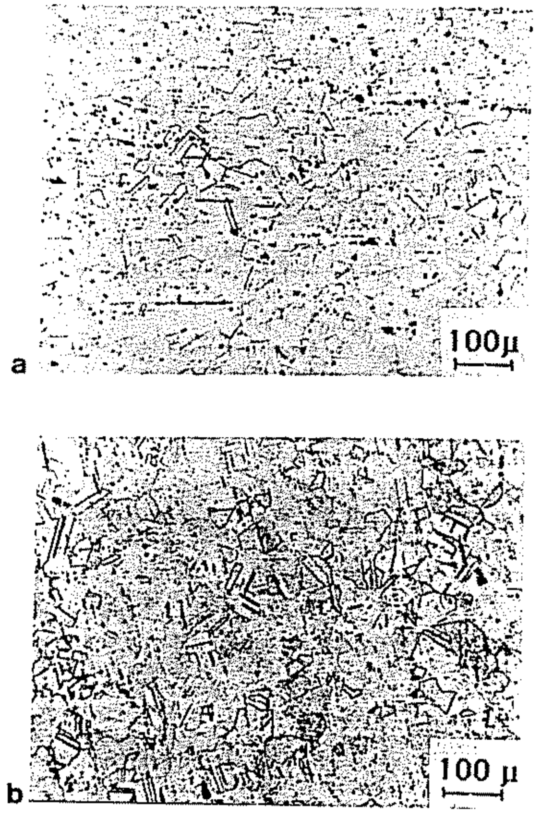

FIG. 1—*Typical microstructure of the material:* (a) *of the bar found at the scene of the crime and* (b) *of the bar found at the suspect's home. (Etchant: nital 2%.)*

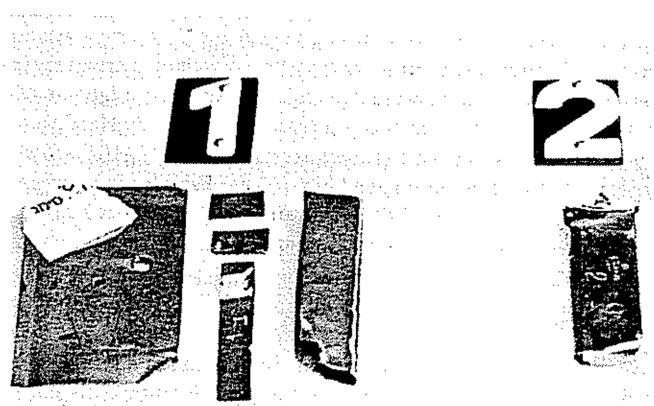

FIG. 2—(1) *Metallic sheet found at the suspect's home and* (2) *cartridge magazine.*

were of similar thickness. Their bright aspect along with the lack of rust suggested that they might be made of stainless steel. In this case too, the need to establish a link between the magazine and the sheet found at the suspect's home arose.

Metallurgical inspection was consequently carried out. Both sheets were found to be weakly attracted by a hand magnet in the vicinity of folded areas, whereas no such attraction was observed when flat and undeformed surfaces were involved. Such a behavior is characteristic of austenitic steels including austenitic stainless steels. This finding was supported by the results of energy dispersive X-ray analysis which indicated that both sheets matched in composition (AISI 3XX austenitic stainless steel series) as shown in Table 1 and Fig. 3.

Metallographic examination was carried out to compare the respective microstructure of the investigated materials. Both microstructures were found to be austenitic with equiaxed grains having an average size of 60 μm (Fig. 4). Some grains were found to contain twins which resulted probably from plastic deformation (sheet forming). In both cases, carbides were observed to be aligned as a result of the forming process. Microhardness testing indicated that both materials were of similar hardness levels ranging from 168 to 178 diamond-pyramid hardness. In this case too, the results of the metallurgical examination increased the probability that the material of the magazine and the sheet found at the suspect's home were of the same origin.

Discussion

The two case histories detailed in this paper demonstrate the role of metallurgical examination in additional information gathering. Composition determination is the first step in metal identification but in itself is not sufficient.

In the first case history, that is, low carbon steel, similar microstructural components (ferrite and pearlite) were expected because this kind of steel exhibits microstructural features which are only mildly dependent on the cooling rates involved during their fabrication. While the martensitic component (indicative of quenched and/or quenched and tempered higher carbon steels) is readily detected by metallographic means, determination of the mean interlamellar spacing of the pearlitic component (cooling rate dependent and typically found in slow cooled steels and low carbon steels) involves much more sophisticated metallographic examination along with statistical processing of the results. However, the fact that in both microstructures the grains were equiaxed and of similar size and hardness along with the same slight tendency for banding indicated an identical thermomechanical history, which gave additional support that both were of the same origin. Moreover, it is well known that two pieces of metal with identical composition will not necessarily exhibit the same microstructure if their thermomechanical history is different, a fact which turns the metallographic examination into a necessary complement of the composition determination.

In the second case, involving austenitic stainless steel, the same degree of similarity between morphology and hardness properties of both sheet metals was observed. This similarity of hardness levels, reflected by the amount of twinning on the microscopic scale, indi-

TABLE 1—*Composition in weight/percent of the sheet metal and the magazine as determined by scanning electron microscopic-energy-dispersive X-ray (SEM-EDX) technique.*

Element	Chromium	Nickel	Silicon	Iron
Sheet metal	20.2	8.2	0.40	balance
Magazine	20.2	8.2	0.34	balance

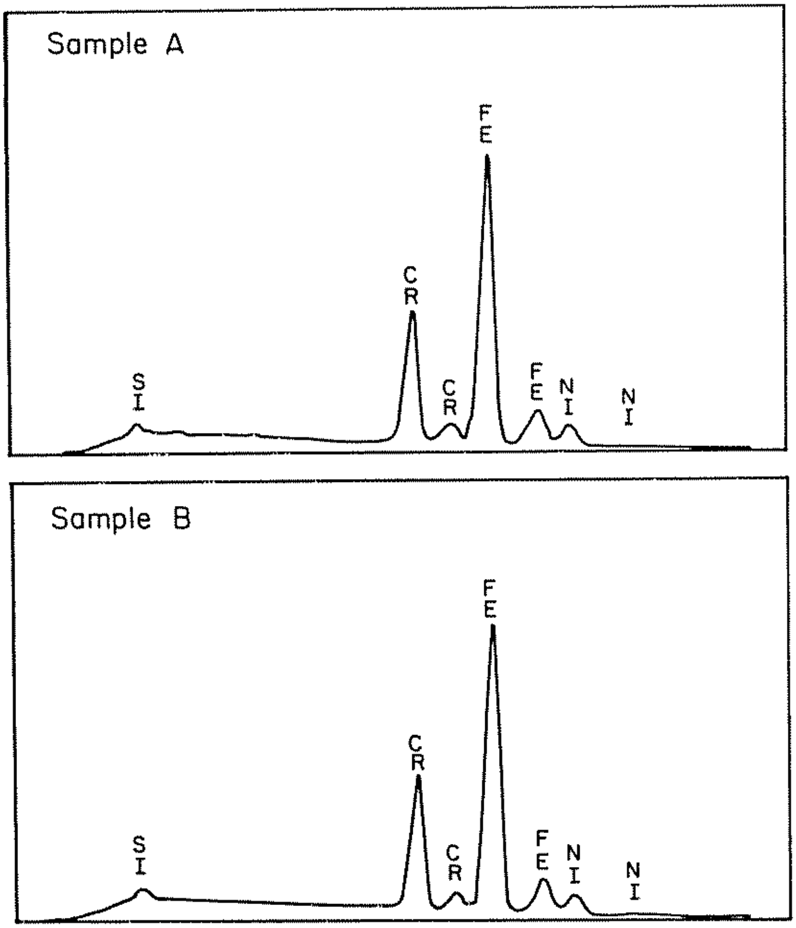

FIG. 3—*Energy dispersive X-ray analysis spectrum (SEM-EDX) of:* (a) *sheet's material and* (b) *cartridge magazine material.*

cated no additional cold work (for example, thickness reduction) was involved in the fabrication of the magazine. Such a finding could have led to search for the forming equipment used and its owners. The degree of cold work was by no means detectable using any other simple technique.

It must be stressed that in order to obtain reliable data as to the microstructure of a material, mainly when comparative results are sought, samples must be taken from identical locations in the object and forming directions must be taken into account, for example, longitudinal and transverse when rolling is involved, otherwise erroneous conclusions may be reached. Such care was exercised in the choice of the samples taken from the steel bars and the stainless steel sheets.

The last point to be emphasized is that metallurgical examination does not replace other information gathering techniques. It rather provides additional and independent information on the material's thermomechanical history which is not obtainable by other techniques commonly employed and thus complements them.

a

b.

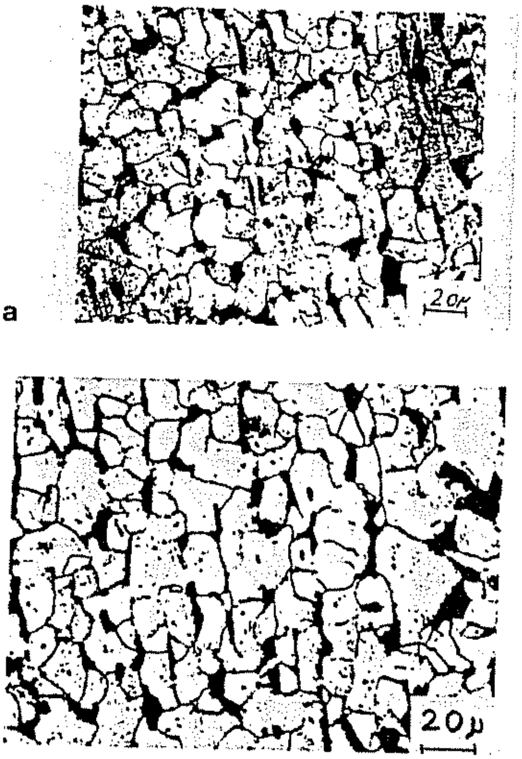

FIG. 4—*Typical microstructure of the material:* (a) *of the cartridge magazine and* (b) *of the sheet metal. (Etchant: oxalic acid 10%.)*

Conclusions

It has been shown by means of the two case histories that metallurgical examination techniques such as those commonly used in failure analysis of materials systems can also be applied to forensic science investigation.

Specifically, metallographic examination can provide additional useful information regarding the thermomechanical history of a material, while such information is virtually undetectable by other conventional techniques such as chemical analysis. Metallurgical examination does not replace existing techniques but rather complements them.

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