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Technical Note

Restoration of obliterated engraved marks on steel surfaces by chemical etching reagent

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ABSTRACT

Chemical etching technique is widely used for restoration of obliterated engraved marks on steel surface in the field of public security. The consumed thickness of steel surface during restoration process is considered as a major criterion for evaluating the efficiency of the chemical etching reagent. The thinner the consumed thickness, the higher the restoration efficiency. According to chemical principles, maintaining the continuous oxidative capabilities of etching reagents and increasing the kinetic rate difference of the reaction between the engraved and non-engraved area with the chemical etching reagent can effectively reduce the consumed steel thickness. The study employed steel surface from the engine case of motorcycle and the car frame of automobile. The chemical etching reagents are composed of nitric acid as the oxidizer, hydrofluoric acid as the coordination agent and mixed with glacial acetic acid or acetone as the solvents. Based on the performance evaluation of three different etching reagents, the one composed of HNO_3, HF and acetone gave the best result.

1. Introduction

Restoration of engraved marks of the original vehicle identification number (VIN) is a very useful technique in the investigation of vehicle theft, robbery and smuggling cases. Among the various methods used to restore to the obliterated engraved marks, chemical etching is the most widely used technique [1–3]. Therefore, it is of crucial importance to the field of public security to develop better chemical etching reagents.

When the restored mark meets the minimal requirement of recognition by naked eyes and photographic record, the consumed thickness of steel surface during restoration process becomes the major criterion for evaluating the efficiency of the chemical etching reagent. The thinner the consumed thickness, the higher is the restoration efficiency [4,5]. Especially when the engraved marks are deeply filed, and the remaining plastic deformation layer is very thin, the consumed thickness of the steel surface is the key to successful manifestation. Moreover, it is also practical to minimize the time required for restoration.

The overall restoration of the engraved marks is achieved by the redox reaction between the chemical etchants and the steel surface. To ensure the continuous oxidation of the steel surface by the etchants, the oxidation potential of the metal should be lowered [6,7]. As a result, the etchant need both strong oxidizer and good coordination agent for the metal ion. In order to meet the minimal requirement of recognition by naked eyes and photographic record, the restored mark must have certain color contrast compared to the substrate, which is caused by the difference by light reflection and refraction. Because the reaction rate of the etchant with the engraved mark is different from the substrate, the densities of the resulting etching products are different and so are the light reflecting properties. So in order to reduce the consumed thickness of the steel surface and restoration time frame, the etching rate difference between the engraved and non-engraved area should be maximized, which means the difference of the activation energy required the etching reaction needs to be amplified.

Other than the inherent chemical properties, concentrations of the reactants and temperature, the permeability of the liquid reagents on the steel surface and the diffusion rates of the gas products formed during the etching process also play important roles in the reaction kinetics due to the heterogeneous nature of the etching reaction [8–10]. In order to further optimize the chemical etching technique for the restoration of obliterated engraved marks, this study utilized the steel surface from the engine case of motor cycle and the car frame of auto mobile. The chosen chemical etching reagents were composed of nitric acid as the oxidizer, hydrofluoric acid as the coordination agent and glacial

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acetic acid or acetone as the solvents. The performance of three different etching formulations were evaluated on the two steel surfaces mentioned above, the causes for the differences in performance were discussed.

2. Material and methods

2.1. Materials and instruments

Steel plate taken from motorcycle engine case and automobile car frame (length: 8–10 cm, width: 2–2.5 cm, thickness: ~0.5 cm); steel number stamp for engraving, steel number file; 600# sandpaper; screwed micrometer; Nikon D40 digital SLR camera.

2.2. Sample preparation

The steel plate from motorcycle engine case was engraved with number "8" by steel number stamp with the device shown in Fig. 1, and the steel plate from the car frame was engraved with number "2" using the same method. The steel stamp was held in a mold (height lower than the stamp to expose it) inside a PVC pipe of which the inside diameter was the same with the outside diameter of the mold. A steel hammer of the same diameter as the mold was allowed to free fall from a constant height to generate the impact for engraving. The depth of the generated engravings could be adjusted with the initial height of the hammer, and were designed to be deeper than what would be obtained from machine engraving so that the number of times of total restoration could be statistically significant to tell the difference between the etching reagents. After the engraving, the number "8"and "2" were obliterated by steel filing followed by polishing with #600 sandpaper until the original numbers cannot be distinguished.

2.3. Etching reagents formulations

The compositions for each etching reagent were listed in Table 1.

2.4. Restoration of engraved marks

Each etching reagent was added onto the obliterated area of the steel surface by plastic pipette at room temperature, the process of restoration was monitored visually. The etched area was swabbed with Q-tip according to the color change of the etching reagent, and new reagent was re-applied until the restored mark reached the minimal requirements of recognition by naked eyes and camera. The results were recorded by Nikon D40 digital SLR camera. Each experiment was repeated for three times and the recorded data were the average of the value of the three experiments.

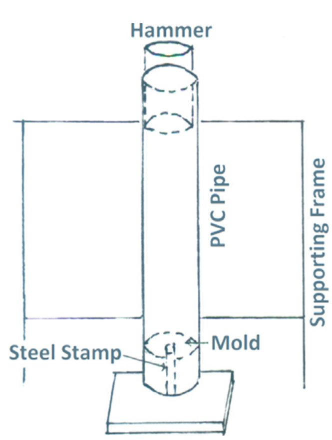

Fig. 1. Device used to engrave the steel plates with steel stamp.

Table 1
Compositions for three etching reagents.

No. of etching reagent	Components and quantity			
	HNO_3 (65–68%) (ml)	HF (40%) (ml)	$C_2H_4O_2$ (99%) (ml)	C_3H_6O (ml)
1	10		15	
2	10	0.5	10	
3	10	0.5		10

2.5. Measurement for consumed thickness of steel plate

The thickness of the steel plate at the obliterated area was measured with screw micrometer before the restoration process. After the result of the first restoration was recorded by camera, the restored mark was obliterated again with #600 sandpaper. The obliterated area was then subjected to the next restoration and record by camera and the restored mark was obliterated again with sandpaper. The process was repeated for 10–15 times until the restored mark was no longer recognizable. The thickness of the steel plate at the obliterated area was measured again, and the thickness difference between the before and after restoration of the steel plate was divided by the total number of restorations to give the average consumed thickness of the steel surface for each restoration process.

3. Results

3.1. Restoration results of steel plates from motorcycle engine shell

The results from etching reagent 1 composed of HNO_3 and glacial acetic acid are shown in Fig. 2.

The results from etching reagent 2 composed of HNO_3, HF and glacial acetic acid are shown in Fig. 3.

3.2. Restoration results of steel plates from automobile car frame

The results from etching reagent 2 composed of HNO_3, HF and glacial acetic acid are shown in Fig. 4.

The results from etching reagent 3 composed of HNO_3, HF and acetone are shown in Fig. 5.

3.3. Comparison of restoration performance between different reagents

Table 2 shows the maximum number of restoration repeats, consumed thickness of steel surface and time required for single restoration process of each etching reagent on the two types of steel plates.

4. Discussion

4.1. Restoration on different types of steel surface

Based on the results shown in Table 2, the consumed thickness of the steel surface, time and volume of etching reagent required for single restoration process are very different between the two types of steel plates using the same reagent 2. These variations could be explained by the different material composition and the manufactural processing for the two types of steel plates. Compared with the steel plate from automobile car frame, the