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An investigation into the suitability of some etching reagents to restoring obliterated stamped numbers on cast iron engine blocks of cars

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ABSTRACT

Most of the automotive companies use cast iron for their engine blocks. Restoration of obliterated number on these iron surfaces by chemical etching is known to be quite difficult. Heating of the obliterated surface using oxyacetylene flame is an alternative recovery treatment suggested in literature and used in practice. However chemical etching has been established to be the most sensitive technique for detection of metal deformation present under stamped serial numbers. Hence, the current work investigated the suitability of some common etchants on cast iron surfaces with a view to determining the most suitable one for revealing the obliterated marks. The reagents tested were mostly copper containing Fry's reagent and its modifications. Two cast iron engine blocks (3.29%C and 3.1%C) of two cars – a Proton Saga and a Toyota – were utilized for the experiments. The engine blocks were cut into several small plates and each plate was stamped with some numerical characters at 8 kN load using Instron Table Mounted Universal Testing Machine. The depth of stamping impression varied between 0.2 mm and 0.3 mm. The stamped number was completely ground off manually using a metal file. The grounded surface was then polished smooth using emery papers and etched with a few selected reagents mostly by swabbing. Experimental results showed that a modified Fry's composition consisting of 45 g $CuCl_2$, 100 mL HCl, and 180 mL H_2O restored the number with better contrast at a reasonably shorter time. The above reagent is a slightly modified form of one of the Fry's original compositions – 45 g $CuCl_2$, 180 mL HCl, and 100 mL H_2O. Quite importantly the proposed reagent restored the original stamped numbers of both Proton and Toyota cars and also a Mitsubishi car that had been obliterated.

The most widely used Fry's composition (90 g $CuCl_2$, 120 mL HCl and 100 mL H_2O), although recovered the obliterated number, did not cause the desired contrast.

1. Introduction

Macroetching tests are the most informative and powerful tools of all the metallographic procedures. Hence they are frequently employed by material scientists for microscopic and macroscopic examination of metal surfaces for quality control, failure analysis and research studies [1,2]. The microstructure of iron and steel had been well documented and many different etchants have been formulated for specific alloys for different conditions. These etchants were mainly developed by material scientists to reveal maximum contrast between pearlite and ferrite or cementite network (the popular natal and picral etching reagents) or reveal structures and for many other metallurgical studies [1–3]. In 1921, Fry [2] originally published a method for revealing strain lines in iron and steel due to cold work using etching reagents. His most popular reagent is 90 g cupric chloride, 120 mL hydrochloric acid and 100 mL water [1–4]; however, a few of its variations are also available [1–7]. Fry's popular composition has been adopted by the forensic science community and is used traditionally to restore the obliterated numbers on the chassis and engine of motor vehicles and frames of firearms [8–16].

Recent work on steel and aluminium surfaces by Azlan et al. [17], Baharum et al. [18], Siaw and Kuppuswamy [19], Bong and Kuppuswamy [20], Norjaidi Uli et al. [21] Levin [22] and Kuppuswamy [23] have demonstrated that the composition of the metal had a great influence on the choice of a reagent. Carbon content in steel also appeared to play an important role in selecting the etchant. Low and medium carbon steel surfaces required different reagents [17,19]. Cast iron, which is a combination of iron with a greater percentage of carbon (2–6%), does not respond well by etching process [6,8,24]. Hence heat

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treatment using oxyacetylene flame for engine number restoration was recommended as an alternative approach [24]. More recently methyl-acetylene-propadiene (MAPP) gas was reported to give results as good as oxyacetylene heating [25]. However, these heat treatment methods required elaborate equipments and are cumbersome. On the other hand etching techniques are simple to apply and quite sensitive when compared to all other recovery methods. Magnetic techniques although non-destructive could not be sensitive enough to magnetize the deformed regions in cast iron.

Metallographic reagents for iron and steel compiled by Homer Research Laboratories, Bethlehem Steel Corp. [3] have recommended three Fry's compositions for revealing strain lines due to cold work. However, they recommended the composition 90 g $CuCl_2$, 120 mL HCl and 100 mL H_2O to be most useful for low-carbon steels, particularly Bessemer and other high-nitrogen grades. Turley [4] after comparing three Fry's compositional variations also selected the above one for etching on plain carbon steels ranging in carbon content from 0.04 to 0.52%. This is the reagent that is most popular among forensic science community. Siaw and Kuppuswamy [19] also concluded that this reagent provided the necessary contrast in restoring obliterated engraved marks on medium carbon (0.31%C) steel. A few of the references recommended using the above Fry's composition for etching cast iron surfaces [9,10,16]. However, Jackson [6] and Nickolls [8] reported that cast iron did not respond well to the treatment of Fry's reagent. They recommended constant application of a solution of potassium dichromate in 10% sulphuric acid by swabbing and also immersion for about 3 h. Nickolls also cautioned that overdevelopment caused the obliteration of the restoration. Till date there is no satisfactory etching procedure on cast iron engine surfaces even though successful recovery using Fry's reagent was reported [12]. Cast iron surfaces are difficult to be etched for successful restoration probably because of the poor plastic deformation it undergoes during stamping.

Hence the current work investigated to determine the efficacy of the various available etchants on cast iron surfaces with a view to recommending the most suitable one.

2. Experimental procedure

2.1. Cast iron sample

Two cast iron engine blocks of cars – one from a Proton Saga (3.29%C) and the other from a Toyota 2L (3.1%C) – were purchased for this work. The carbon content was in weight percent. Their hardness values were 213.6 HV (Proton Saga) and 140.2 HV (Toyota 2L). The carbon content was determined in a laboratory following the test method: IS 228 (P-20)-2003. The procedure used in the laboratory was as follows: weighed sample (0.1 gm of cast iron) was taken in a ceramic combustion boat and heated to 1050 °C and melted with flux and constant flow of oxygen. The carbon dioxide generated was measured and the % carbon was estimated by comparing the carbon content of a standard specimen.

The engine blocks were cut into several small plates for the etching experiments.

2.2. Stamping the cast iron plates

The cast iron plates were stamped with numerical characters "18" at 8 kN using a computerized mechanical compression machine Instron Table Mounted Universal Testing Machine model 3367. Hunter brand punch size 7 with hardness value 592.6 HV was used for stamping the number. The pressure 8 kN was determined after a few trials to cause a sufficient depth in the impression. The depth of stamping was found to vary between 0.2 mm and 0.3 mm (the difference in thickness measured using micrometer gauge before and after erasing the stamped number by grinding).

The depth measurements were carried out on the engine number of the Proton Saga car at different locations of the same character using Alicona Infinite Focus. The depths varied among the numbers. The variations were in the range 125.66–286.37 μm. They are comparable to the depths we obtained during stamping characters. Depth measurements of engine number of Toyota 2L car could not be done because of the difficulty encountered in cutting the number portion for testing.

2.3. Obliteration of the stamped marks

2.3.1. Erasure using a metal file

The number "18" stamped on the iron plate was ground off manually using a metal file until no trace of it was visible. The erasure part was the most challenging. First, it was time and energy consumed because the cast iron was a very hard metal. It took nearly 30–60 min to erase the stamped number and to give it a sufficiently smooth polish on each individual plate. Second, each stamped character (1 and 8) was erased evenly and carefully so that the indentation marks were obliterated to the same depth. This was important because uneven and too deep obliteration would have removed the plastically deformed region; this could result in the failure of the restoration of the obliterated stamped marks. There were 30 such erased plates prepared for etching with reagents.

2.3.2. Obliteration by overstamping

The stamped number "18" was totally ground off by hand filing. A new number "26" was overstamped in two ways in the area erased by filing. First a different (smaller) sized font was used to punch the number 26 by hammering. Second a similar sized (as the original number) stamp was used to punch the new number 26 using the same force 8 kN originally used to stamp the character 18. A total of 3 such overstamped plates were prepared.

2.3.3. Obliteration by centre punching

The original stamped number "18" was obliterated by hammering using a centre punch. The shots were punched closely surrounding the number so that the number "18" was not decipherable visually. Two such plates were prepared for testing.

2.3.4. Obliteration of original engine numbers on the Proton Saga and Toyota 2L cars

A few digits of the original number were deeply erased using a metal file.

2.4. Etching reagents

Eight metallographic reagents were tested on the surfaces obliterated by filing. Their composition and the sources are given in Table 1.

2.5. Etching procedures

2.5.1. Polishing

Every obliterated area of the metal described in Section 2.3 was polished using silicon carbide abrasive papers of different grades proceeding from coarser to smooth paper to give the surface a smooth finish before etching the surface. Three different grades of abrasive papers were used on most of the samples: coarse grade (P60), medium grade (P120) and fine grade (P320) for polishing. Polishing with P320 gave a reasonably smooth finish. The coarseness of the paper was decided upon the roughness of the surface [5]. Some of the obliterated marks were also polished further using 1200 paper to remove the previous scratches caused by the earlier papers. In the latter cases the obliterated surfaces took a mirror finish. The main purpose of polishing was to remove very superficial scratches and ridges from the surface that would otherwise show up as background noise [26]. However, care was taken that excessive polishing that might have removed the deformed layer of interest was avoided.

2.5.2. Etching by swabbing/immersion

The reagents were applied by swabbing as swabbing provided control over etching. However, the etching reagent 3 was applied by both swabbing and immersion as suggested elsewhere [6,8]. The sample surface was thoroughly cleaned with acetone before etching. The surface was then swabbed by rubbing the obliterated surface with cotton wool moistened in the reagent for about 10–15 s. The swabbing was done until the obliterated number was restored. In the immersion technique a plasticine wall was built around the obliterated area and the etching reagent was poured using a syringe. The etching reagent was replaced during every 30 min intervals and the surface was observed for any number recovery.

Of the above two engine blocks – Proton Saga and Toyota 2L – etching experiments were performed first on the Proton Saga car. Later the results were tested on the cast iron engine block of the Toyota 2L car. The etchant that provided the desirable contrast of the restored marks on both engine blocks was determined to be the most suitable one.

2.6. Testing of the selected reagent for its sensitivity

The selected etchant was applied on surfaces in which the numbers were obliterated by overstamping and centre punching. The obliterated surfaces were polished using emery papers before swabbing with the reagent.

The efficacy of the reagent was also tested on the original engine numbers of both Proton and Toyota cars and also on an engine block of a Mitsubishi car. In all these cases the original numbers were obliterated by metal files and polished with emery papers and etched by swabbing.