An example of the infusion of endogenous technology in engineering curricula: the case hardening of mild steel using local Jamaica blue mountain coffee shells

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ABSTRACT: The application of science and technology for the creation of endogenous technologies is a veritable means of achieving rapid industrialisation. This, however, requires skilled technical labour, which is motivated to create endogenous technologies. Therefore, in this article, the authors report on a typical methodology in the infusion of an endogenous technology for the case hardening of mild steel. This study, which was carried out by a group of senior engineering students, evaluated the possibility of improving the strength and hardness of low carbon steel by a diffusion method using the elements of nitrogen and carbon available in dry coffee husks. The hardness of each was studied as a function of time and temperature. The mass of dried coffee husk used was held constant at 400.0g for each specimen, with the only variables being time and temperature. Nine specimens were utilised at three independent diffusion times and temperatures. The treated metals were characterised in terms of their hardness. The results indicated that dry blue mountain coffee husks can be used to achieve sufficient hardness in low carbon steel.

INTRODUCTION

There seems to be no generally accepted definition of endogenous technology, but it can be taken to cover technology that makes the best usage of the local resources of a particular country or region [1]. It does not exclude the adoption of *foreign* or *international* or exogenous technology, but such technology must necessarily be adapted to suit the particular needs, conditions and resources of the developing country.

The development of endogenous technologies may not attract the attention of engineers and technicians in industrialised or advanced countries. Nevertheless, it requires highly qualified and skilled engineers or technicians, since a high degree of competence is needed to determine how certain technology can be adapted to suit different environments (technical infrastructure, climate, culture, quality of labour, raw materials, etc) in developing countries.

Moreover, the development of endogenous technology almost always requires innovation and is, therefore, as much a challenge for well-qualified personnel as in the development of some of the most sophisticated new technologies.

Endogenous technology should not be considered a second-class technology; this is because it requires the best and most qualified talents if it is to be properly carried out. It may not be *glamorous* or *sophisticated* compared to, for example, space research or mobile radio communications. However, it is no less challenging, no less demanding of the best and no less unforgiving of error or omission.

CASE HARDENING OF MILD STEEL

The need for surface hardened mild steel for components and spare parts for maintenance work has always been a high priority for Jamaica. The conventional mode of pack cyaniding involves the use of potassium ferro cyaniding, which is expensive and toxic [2]. Therefore, there is a need to seek the adaptation of exogenous technologies that are relevant to the immediate local environment, which can then be utilised to challenge students to solve real, significant and meaningful problems in order to give them a feeling or sense of self confidence, accomplishment and pride.

To this end, a suitable local material based upon the work of Ibironke et al was used to replace potassium ferro cyaniding for the case hardening of mild steel [2]. In this study, coffee shells/husks were used, based upon the work of Titus et al, which showed that the nutrients' composition were comprised of 1.5% nitrogen, 0.5% phosphorous and 2.2% potash [3].

EXPERIMENTAL PROCEDURES

Mild steel of 0.3% carbon was utilised in order to produce nine rectangular specimens of the dimension, 24 mm x 12 mm x 18 mm. The preparation began with grinding the mild steel blocks to the required dimensions shown in Figure 1. This operation was conducted on a surface grinder. Subsequently, the specimen was packed in a cast iron pot of thickness 5 mm and volume 0.0009 m^3.

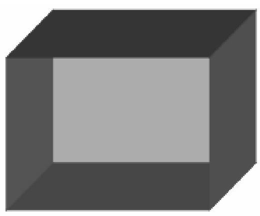


Figure 1: Dimension of 24 mm x 12 mm x 18 mm.

The pot was packed with nitrogen/carbon carrying agents. Dry Blue Mountain coffee shells were procured from the Silverdene farm (Linstead St Catharine) and stored at room temperature for five days, during which samples were removed from the containers on a daily basis for used in the experiment.

For this study, 400.0 grams of Blue Mountain coffee shells were placed in the cast iron pot and then compressed using a Dake compression machine. After this, the cast iron container was sealed with high temperature resistant clay and placed in the oven at a predetermined temperature and time as shown in Table 1.

Table 1: Time and temperature variations.

Experiment	Temperature	Time (hrs)	Mass of coffee used (g)
1	850^o C	3	400
2		6	400
3		9	400
4	950^o C	3	400
5		6	400
6		9	400
7	1,050^o C	3	400
8		6	400
9		9	400

Upon completion of the heat treatment process, the specimen was removed from the container and quenched in water at a temperature of 25^o C.

Subsequent to the heat treatment process, the specimen was cut into two halves perpendicular to the longest heat-treated surface. The specimen was then transferred to a METASERV polisher-grinder on which the rough surfaces and dark spots were removed. The grinding process was started on a 240-grade abrasive paper and lasted for approximately 30 minutes, after which it was transferred to a 400-grade abrasive paper and grounded for 15 minutes. The final grinding took place on a 600-grade abrasive paper and lasted for another 15 minutes.

Hardness Test

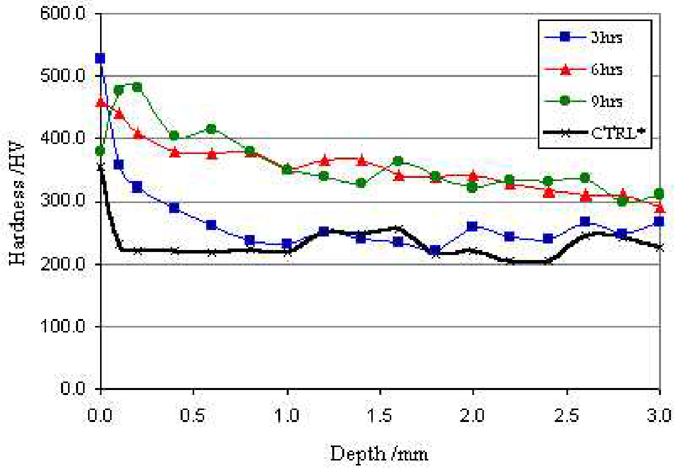
The static indentation hardness test employs the principle of exerting a load on an indenter, which, in turn, deforms the specimen. In accordance with the American Society for Testing and Materials (ASTM) specifications, the micro-hardness test was conducted using the HM-122 digital video Vickers micro-hardness tester. A load of 0.3 kilograms was applied for 15 seconds so as to produce the indentation in the surface of the specimen.

The hardness of the specimen was determined from the resulting indentation by finding the ratio of the applied load to the indented area. In conducting the test, the samples were ground and polished to remove any dark spots and scars produced on the surface during the surface hardening process so that the indentation could be easily distinguished.

RESULTS

Figure 2 shows the hardness profile as a function of the depth of the case for the following parameters: temperature of 850^o C for intervals of three hours, six hours and nine hours. A comparison of the curves shown in Figure 2 shows that, as the diffusion time increased, the case-depth of the material also increased. Careful analysis of the cross section of the specimen revealed that the material had some significant variations in terms of the micro-hardness. Despite the variations in the micro-hardness values, there was a consistent reduction in the hardness of the specimen measuring from the surface to the centre.

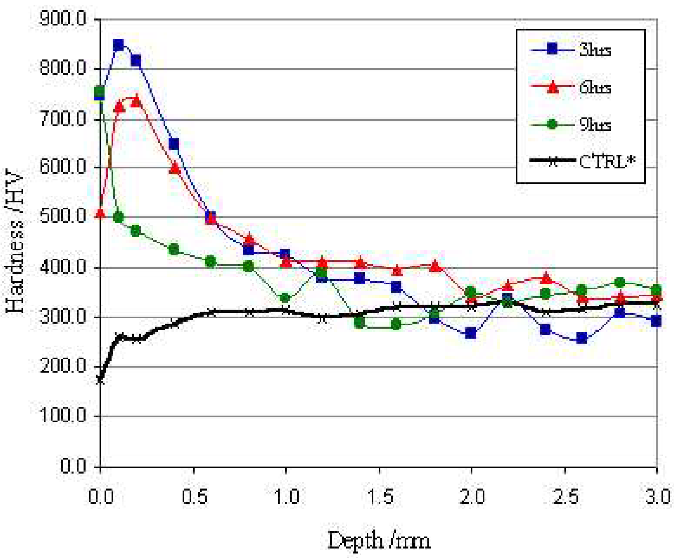
In addition, Figure 2 also reveals that, at a diffusion temperature of 850^o C, a case depth greater than 3.0 mm was obtainable at a diffusion time of six hours and greater. While at three hours, a case depth of 1.2 mm was achieved.



Note: CTRL* = untreated mild steel

Figure 2: Hardness values obtained using Blue Mountain coffee shells at 850^o C when the time is varied.

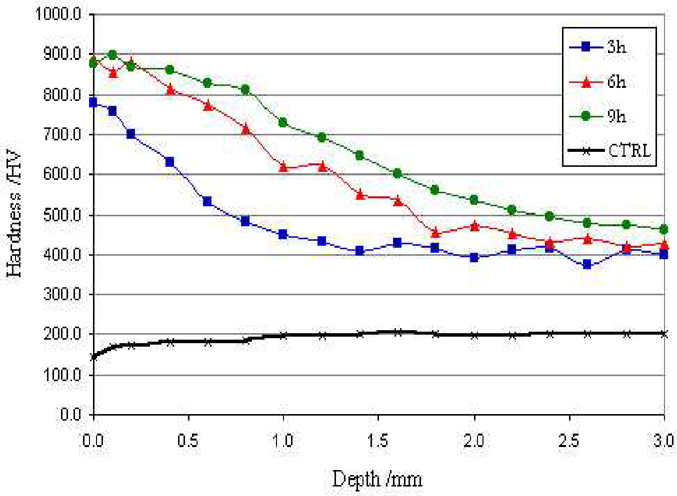
Figure 3 shows the hardness profile as a function of depth of the case for the following parameters; temperature of 950^o C, for times of three-hour, six-hour and nine-hour intervals. A comparison of the curves shown in Figure 3 shows that as the diffusion time increases from three to six hours the case hardness and the case-depth of the material also increases. However, upon increasing the time to nine hours, a reduction in the average hardness and case depth was observed.



Note: CTRL* = untreated mild steel

Figure 3: Hardness value obtained using Blue Mountain coffee shells at 950^o C when time is varied.

When comparing the curves shown in Figure 4, it can be seen that at nine hours, the hardness values were significantly higher than those derived from a diffusion treatment of three or six hours. All the specimens maintained a case depth greater than 3.0 mm for all three time-periods tested.



Note: CTRL* = untreated mild steel

Figure 4: hardness value obtained using Blue Mountain coffee shells at 1,050°C when the time is varied.

However, a comparison of Figures 2 and 3 shows that the hardness is primarily dependent upon the diffusion temperature, not the diffusion time. On the other hand, the case depth was more dependent on the diffusion time than it was on the diffusion temperature.

As such, it is expected that if a high process temperature is maintained for a period greater than nine hours, a case-depth in excess of 5.0 mm is possible with a uniformly harden surface.

DISCUSSION AND CONCLUSION

The inclusion of this type of Problem-Based Learning (PBL) methodology in the course should result in the formation of a cadre of well rounded, engineering graduates, who are well prepared and motivated to contribute to their country's development.

From this specific PBL programme, the following conclusions are made:

- The possibility of pack cyaniding mild steel using Blue Mountain coffee husks as a source of C and N has been demonstrated for the first time;
- Mild steel can be case hardened by utilising the waste from the locally grown Blue Mountain coffee;
- From the curves obtained in Figures 2 to 4, the case depth prevails as both time and temperature characteristics of a typical diffusion process, displaying an Arrhenius equation of the form:

$$\text{Rate} = C^{-Q}/RT \text{ [4].}$$

where Q is defined as the activation energy per mole, R is the universal gas constant per mole and T is the temperature.

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Conference Proceedings of the *8th UICEE Annual Conference on Engineering Education* under the theme: *Bringing Engineering Educators Together*

edited by Zenon J. Pudlowski

The *8th UICEE Annual Conference on Engineering Education*, held under the theme of *Bringing Engineering Educators Together*, was organised by the UNESCO International Centre for Engineering Education (UICEE) and was staged in Kingston, Jamaica, between 7 and 11 February 2005, with the University of Technology Jamaica (UTech) as the host and principal co-sponsor.

This volume of Proceedings includes a range of diverse papers submitted to this Conference that detail various international approaches to engineering education research and development related to the Conference theme, as well as other specific activities.

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