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The quality control of graphitic irons using the ultrasonic method: the Jamaican experience

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ABSTRACT: Graphite shape, distribution and size for various types of cast iron are primarily dependent upon the chemical composition and cooling rate of the cast. In Jamaica, small foundries that use scrap for casting encounter difficulty in controlling the chemical composition of castings. The objective of this study was to investigate the relationship connecting ultrasonic velocity to graphite form, plus its distribution and size, and to establish a satisfactory method of selecting homogenous scraps of grey cast iron. The morphology of the samples and their associated ultrasonic velocities are discussed in the article. The range of ultrasonic velocities associated with the graphite form of scrap tested in this study was found to be too wide for ultrasonic testing (UT) to be used as a quality control methodology for the selection of grey cast iron, based upon microstructure.

INTRODUCTION AND LITERATURE REVIEW

A quick inexpensive testing method for the quality control of homogenous graphitic iron scraps is desirable by producers of cast iron products. For this reason, some authors have suggested ultrasonic velocity and resonant frequency measurements as possible solutions to this problem [1][2].

In Jamaica, sugar mill roller shells are typically cast from scrap cast iron and/or worn damage sugar mill roller shells. The mill roller shells are traditionally made of high phosphorous and high manganese, grey cast iron [3].

Since chemical composition affects graphite form, the ultrasonic velocity of the material could, therefore, be used for quality control if a correlation is to be developed between ultrasonic velocity and graphite form, and its distribution [4]. However, comparative ultrasonic testing on a run of identical castings can indicate whether a satisfactory structure is being maintained, once it has been established. The key question then is: *What is the relationship between ultrasonic velocity and cast iron graphite form and distribution?*

Ultrasonic velocity has been utilised for many years in the checking of the graphite form in graphite cast irons, especially as a routine check on nodular graphite irons [5]. Ultrasonic velocity measurements form a satisfactory quality control method and, since it is based on a fundamental property of the material (the modulus), it has a claim to acceptance.

This study, therefore, seeks to use ultrasonic testing within its limits, in foundries in order to select a constant product and enables all scrap cast iron supplied to be inspected for graphite form, thus grouping them according to graphite structure before re-melting.

MATERIAL AND EQUIPMENT

The materials utilised for the primary making of cast iron casting products are typically scrap cast iron. Similarly, the samples used in this study were selected from a scrap heap. The samples used in this research study are listed in Table 1.

Table 1: The samples selected.

Sample No.	Samples Used	Thickness Range (mm)
1	Manhole cover	15
2	Pipe	29
3	Runner	18
4	Engine block	8
5	Engine head	15-23
6	Tractor drive housing	16
7	Tractor housing	12
8	Brake drum	14
9	Connecting rod	24
10	Cam shaft	22

A Krautkramer USN 52 Digital Ultrasonic Flaw Detector was then used to measure the ultrasonic velocity of the cast iron samples, whereas frequency was provided by a 2.5 MHz, straight beam, single-element transducer. A block diagram of the main components of the instrument is shown in Figure 2.

A general-purpose petroleum-based couplant was used in conjunction with the transducer. This provides an air free interface between the transducer and the test material calibration. A standard calibration block for straight beam transducers was used for calibration after connecting the transducer.

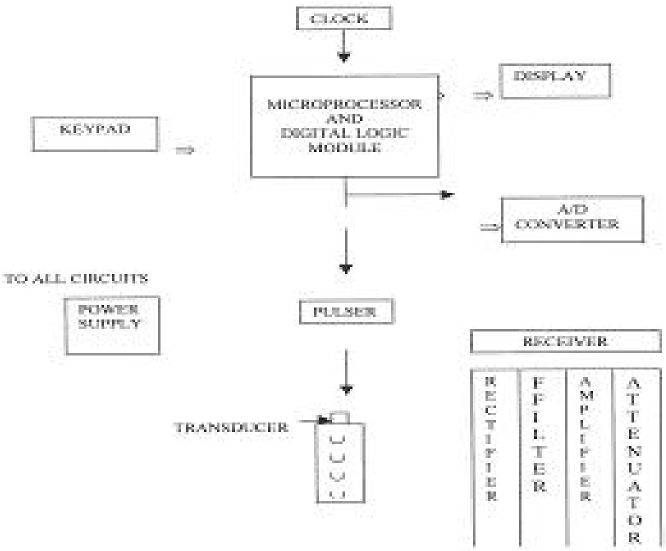

Figure 2: Digital flaw detector block diagram [6].

SAMPLE CHARACTERISATION

The velocity measurement was obtained through a material calibration process. A micrometer was used to measure the thickness of the sample. The delay key on the instrument was used to align the electric zero with the acoustic zero. The transducer was then placed on a sample and the distance between the echoes on the screen adjusted using the material velocity keys until it corresponds with the micrometer reading. The material velocity was then read directly from the display.

A small section of each sample was subsequently removed, ground, polished, using 0.03% alumina, and etched with 4% picral. The microstructure was then observed under an optical microscope.

RESULTS AND DISCUSSION

The morphology of the samples studied shows the grey cast iron to be mainly ASTM V11 form with type C distribution, and sizes 5 and 6. The matrix form of the grey cast iron samples were generally pearlitic, ranging from approximately 97-100% pearlite, as listed in Table 2. Figures 2-11 show graphite forms taken from the various samples.

A microstructure of the connecting rod shown in Figure 10, contains approximately 50% pearlite. Figures 2, 3, 7 and 8 show that Phosphide eutectic was present in samples 2, 3, 7 and 8; however, there was no graphite formation on the camshaft and connecting rod samples, as shown in Figures 9 and 10.

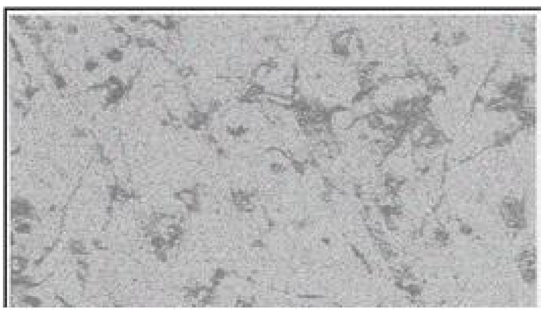

Figure 2: Sample #1 (cast manhole cover), graphite form - ASTM VII, type C distribution, size 5; ultrasonic velocity of 4.8 km/s.

Table 2: Matrix of the results for the various cast iron samples.

Sample #	Samples Used	Graphite Form	Percent Pearlite	Ultra-Sonic Km^{-S} Velocity
1	Manhole cover	ASTM VII	99	4.8
2	Pipe	ASTM 111	99	4.7
3	Runner	ASTM VII	97	4.5
4	Engine block	ASTMVIl	98	4.7
5	Engine head	ASTM VII	100	4.5 - 5.2
6	Tractor drive housing	ASTM VII	97	4.4
7	Tractor housing	ASTM VII	98	4.8
8	Brake drum	ASTM VII	99	4.8
9	Connecting rod	ASTM 1	50	5.9
10	Camshaft	NONE	-	5.1

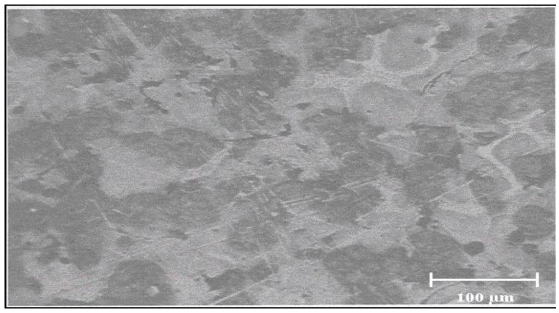

Figure 3: Sample #2 (cast pipe sample), graphite form - ASTM 111, type C, note phosphide eutectic; ultrasonic velocity of 4.5 km/s.

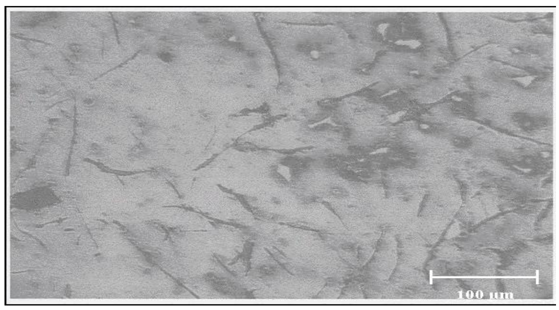

Figure 4: Sample #3 (cast runner sample), graphite form - ASTM VII, type C, note phosphide eutectic; ultrasonic velocity of 4.4 km/s.

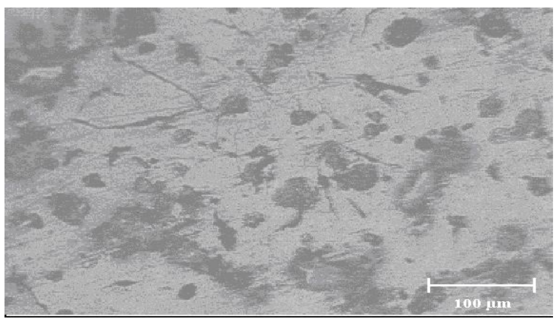

Figure 5: Sample #4 (engine block sample), graphite form - ASTM 1, type C; ultrasonic velocity of 4.7 km/s.

The ultrasonic velocity for the grey cast iron samples ranges was from 4.4 km/s to 5.2 km/s. In general practice, ultrasonic velocity in grey cast iron ranges from 3.5 to 4.9 km/s. While compacted iron graphite ranges from 5.1 to 5.3 km/s and nodular graphite iron above 5.6 km/s. The actual velocities measured depended upon the coarseness of the graphite and varied with the matrix [7].

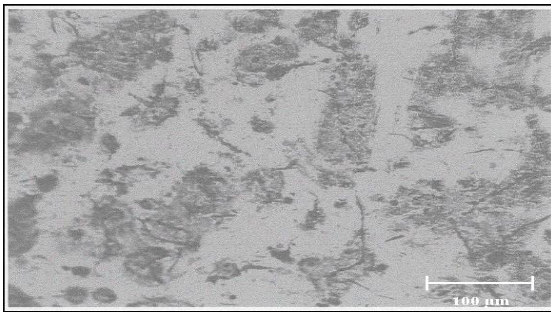

Figure 6: Sample #5 (engine head sample), graphite form - ASTM VII, type C, size 6; ultrasonic velocity of 4.5-5.2 km/s.

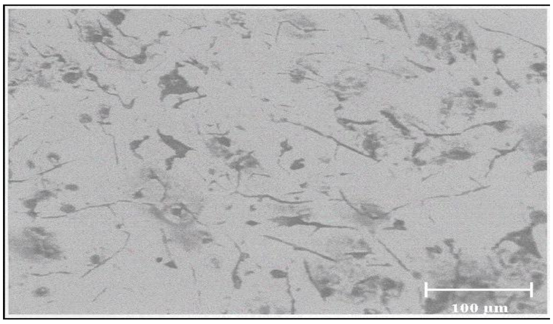

Figure 7: Sample #6 (tractor drive housing sample), graphite form - ASTMVII, type C, size 5; ultrasonic velocity of 4.5 km/s.

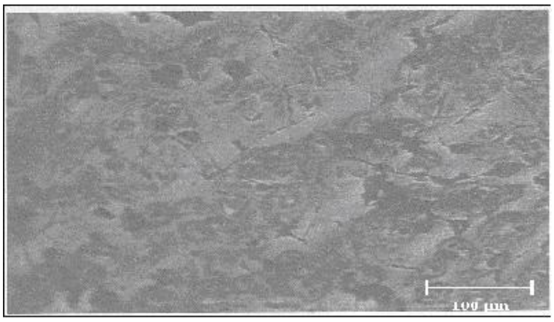

Figure 8: Sample #7 (tractor housing sample), graphite form - ASTM 111, type C, size 5; ultrasonic velocity of 4.5 km/s.

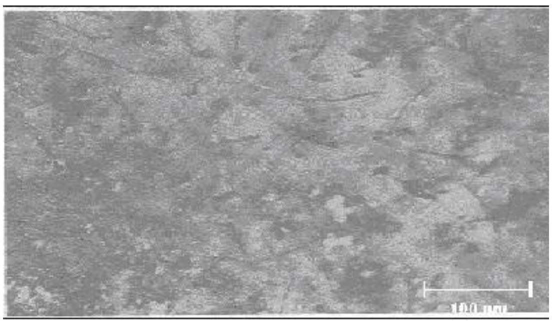

Figure 9: Sample #8 (brake drum sample), graphite form – ASTMI, type C, size 5; ultrasonic velocity of 4.6 km/s.

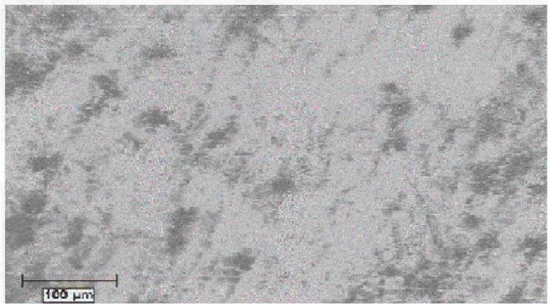

Figure 10: Sample #9 (connecting rod), graphite form - ASTM VI, fully nodular graphite; ultrasonic velocity of 5.9 km/s.

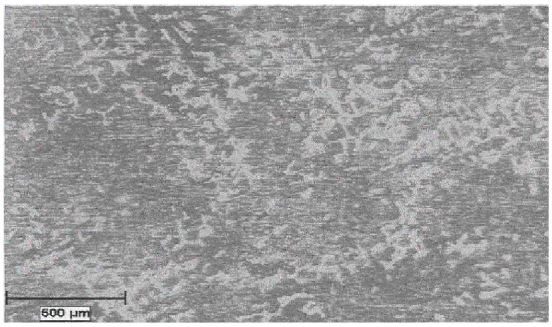

Figure 11: Sample #10 (camshaft), graphite form - 20% nodularity; ultrasonic velocity of 5.1 km/s.

Further examination of the actual engine head shows variation in the ultrasonic velocity from 4.5 km/s to 5.2 km/s. The highest velocities (5.2 km/s) were found to be nearest the valves. The velocity decreased towards the edge of the block, where it was 4.5 km/s. This is clearly due to the heating cycles during the combustion of the engine. Diesel engines heat air up to 10,000°F, and at this temperature, the iron would maintain its crystalline form, but the grain size would be affected. If the engine overheats to the austenite region, there could be variation in the crystalline structure, as well as the grain size.

A relatively good correlation was found when comparing the matrix form in the grey cast iron samples with the ultrasonic velocity (see Table 2). The samples with a high percentage of pearlite (98-100%) possessed the higher ultrasonic velocities (4.7-5.2 km/s), while those with a lower percentage pearlite (97%) had lower ultrasonic velocities (4.4-4.5 km/s).

The samples that had phosphide eutectic (1, 2, 3, 7 and 8) had ultrasonic velocities of 4.7 km/s, 4.5 km/s and 4.8 km/s.

Figure 12 shows the wide range of velocities associated with this characteristic. The velocities here may be due to the quantity of the phosphide eutectic present.

CONCLUSIONS

From the samples studied, no single ultrasonic velocity was found that could be related to a particular graphite form.

The wide range of ultrasonic velocity values associated with the ASTM VII graphite form suggests that there is no direct correlation between them for the purpose of quality control. Generally, ultrasonic velocity increases with percentage pearlite in the grey cast iron samples studied. The phosphide eutectic present in the matrix did not produce a single or a narrow enough band of values to establish a direct relationship with ultrasonic velocity.

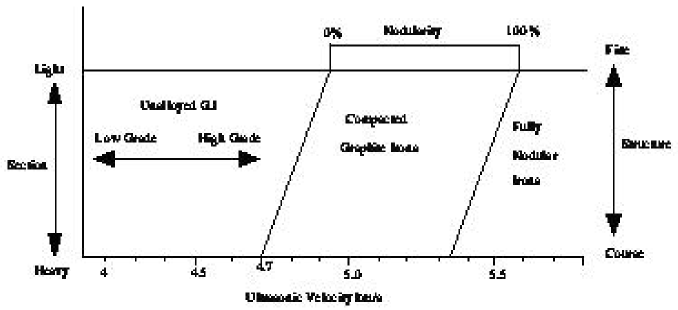

Figure 12: General change of ultrasonic velocity with graphite formation and coarseness.

Without knowledge of the heat treatment history, as seen in the engine head example, it is impractical to associate a particular velocity measurement to a graphite form or chemical content, especially without the knowledge of the matrix microstructure.

Therefore, scrap cast iron, as used for making sugar cane mill rollers shells, is not a good candidate to be subjected to ultrasonic testing for homogeneous microstructure quality control.

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