Use of Low-frequency Eddy-current Systems when evaluating Structural Changes in Cast Iron

By D. R. Beard

The author describes the use of a low-frequency eddy-current system for the evaluation of structural changes in cast iron. It is shown that this technique has potential as a shop-floor inspection tool for identical repetition-type castings. Although at the present time, such a system will only indicate that one sample is different from another, it is hoped that it will be eventually possible to assess why the component under test is different from a standard item.

Where approval is required, the assessment as to whether cast-iron components are to specification has always required evaluation of structural, mechanical and hardness properties. These, by their very nature, are time-consuming operations, liable to create delay in the despatch of castings to the customer or to the machine-shops. In an industry where production targets have to be maintained, a low-cost rapid-sorting method for castings would be a welcome addition to any foundry quality-control or laboratory function.

For some years, steels have been successfully sorted according to metallurgical or chemical differences, using a magnetic bridging system which compared test samples with a known standard. It was decided, therefore, to run a series of trials in the author’s foundry using such a system. On application to the various manufacturers, it became obvious that the equipment fell into two basic groups: high- and low-frequency. The low-frequency system was considered preferable as it gave a deeper penetration of the components under test. This was expected to eliminate surface effects of the type often found when examining heat-treated cast irons.

Principle of Operation

Alternating current passed through a coil will generate an alternating magnetic field. Introduction of a ferromagnetic component into this field will cause eddy currents to be induced within the component, dependent on the strength of current flow, material composition, type, etc.

A standard eddy-current system comprises two such coils connected via an electronic summing device, to a cathode-ray tube display. Each coil is fed alternating current 180° out of phase, resulting in a balanced display on the cathode-ray tube. If a component is placed in or on the standard coil, eddy currents will be induced, resulting in the loading of that coil. There is now an out-of-balance condition shown on the cathode-ray tube. If a similar sample is placed in or on the test coil, a balanced situation will return. If this sample is different in any way, structurally or chemically, then to a certain degree an out-of-balance situation will be displayed. Calibration of the degree of “out-of-balance” will allow an assessment of material acceptability to be made after cross referencing has been carried out using standard metallurgical and chemical methods. In time, experienced operators should be able to reduce the amount of over-checking required. The basic principles of the system and resultant cathode-ray traces can be seen in fig. 3, whilst figs. 1 and 2 show

Die Verwendung von Niederfrequenz-Wirbelstrom-Systemen bei der Bewertung von Strukturrellen Änderungen in Gusseisen

von D. R. Beard


L’emploi des équipements à courants de Foucault à basse fréquence à l'évaluation des modifications de structure de la fonte

par D. R. Beard

L’auteur décrit l’emploi des équipements à courants de Foucault à basse fréquence pour évaluer les modifications de structure de la fonte. Il démontre l’utilité éventuelle de cette méthode pour le contrôle en atelier des pièces coulées en grande série.

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1 The Teledictor Type 1136 ferrous segregator which was used in this research as the instrument for measuring the degree of "out-of-balance" between two castings.

the actual unit, coils and suggested jigs for various applications.

In relating the potential of such a system to the known problems existing in a centrifugal-casting foundry handling a very wide selection of irons ranging in type from flake graphite to spheroidal and from malleable to carbide, it was decided to apply the equipment to four specific areas. Trials were therefore undertaken under the following headings:

2 The various forms of coil which were used to induce magnetic fields into the castings under test. A is a flat coil onto which the components were placed. B is an encircling coil which gave a greater response as components can be placed inside. This can be produced in a range of sizes. C is a flat coil with supports for testing bar or tube, and D is a wooden tube locator for encircling coil. Tube with a larger diameter than the coil can be tested on this rib. All the coil supports were made in wood or plastics to avoid the magnetic fields.

1 Segregation of grey irons which have been altered structurally by heat-treatment;
2 sorting of grey irons having varying elastic properties;
3 segregation of grey irons containing ferrite, and
4 confirmation of the existence chill in castings.

Segregation of Grey Irons which have been altered Structurally by Heat-treatment

Four components were taken and each heat-treated in a different manner as shown below:

- a. Hardened from 880°C, quenched in oil and tempered at 640°C;
- b. hardened from 880°C, and quenched in oil (retained in the hardened condition);
- c. normalised from 880°C, and 
- d. annealed at 1,000°C to promote ferrite deposition.

Each component was then machined in order to remove any surface scale liable to influence the sensitivity of the sorting bridge, or the attitude of the operator. A standard sample was also prepared, this being hardened at 880°C and tempered at 640°C. A slight difference in graphite form was found between sample a and the prepared standard. This would account for the deviation from balance shown on the cathode-ray tube.

The resultant cathode-ray tube traces showed clear segregation. The need for this type of heat-treatment differentiation would not normally occur, but the trials were set up to confirm the principle of segregation. However, further work on components tempered in 10° steps between 590°C and 670°C also showed clear segregation. This latter type of heat-treatment situation occasionally occurs in the ferrous-component industry due to furnace over-shoots or pyrometry failures, etc. This would normally require the complete batch of suspect components being re-hardened and tempered if soft, or re-tempered if hard. Sometimes in such a case, a certain number of components are within specification and would require a 100% hardness check to reveal them, the remainder being retreated. This is a time-consuming operation usually amounting to around 90 sec. per component. After setting the sorting level on the bridge, a time of 2.5 sec. per component was recorded. Typical microstructures and their associated cathode-ray tube traces can be seen in fig. 4.

Segregation of Grey Irons having Varying Elastic Properties

Using a standard of known elastic properties, it was
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Possible to sort a batch of components in which a random check had revealed varying degrees of
which can affect performance, especially those in
the case of piston rings and valve guides. These are
structures, chemical composition or induction machine
properties of piston rings in the case of piston rings. The
use of a probe check in the case of pistons, thus
enabling a suspect batch to be dealt with accordingly.

3. The principle of the method is to balance two induced fields
one against the other. If the balance is at a straight line, if out of
balance a point of minimum added power. By plotting
the cathode-ray tube traces obtained can be seen in
the sensitive microstructures and their relationship to
production at a point of minimum added power. Further
investigations proved variations in Zn values in
relationship to pressure.
Segregation of Grey Irons Containing Ferrite

Several components were specially produced to contain ferrite. A component containing zero ferrite in a wholly-pearlitic grey iron, was used as a standard. The ferritic components were mixed with a normal production batch and presented for segregation. All the suspect components were found during the bridging tests.

Confirmation microstructures and a copy of the cathode-ray tube trace can be seen in fig. 6. In all centrifugal-casting foundries, ferrite levels are strictly controlled according to internal standards. The segregator offers a form of sorting that would eliminate or greatly reduce the 100% micro-check normally carried out, and b could be used on finished components.

Confirmation of the Existence of Chill in Castings

All cast irons may be susceptible to chill at the casting stage and certain types require a 100% inspec-
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that the present trials will be extended on a production basis. This should produce more information so that a quantitative assessment of material structures can be obtained from the equipment rather than using it as a simple go/no-go gauge.

At present, the author's department is able to tell that one sample is different from another, but not why. This information is considered to be necessary, and should come with experience.

The only drawbacks found with the equipment were:

a. The need that each component under test should be identical in size.

b. Each component, subsequent to testing, should be kept separate from any other untested castings, as when these are screened the magnetic field will be affected in an adverse manner.

A comparison of the traces produced by samples which had undergone differing chill histories. A Small particles of carbides in a matrix of tempered martensite. B Heavy concentration of carbides tending towards acicularity in a matrix of tempered martensite.

8 The equipment is actually detecting differences in conductivity and permeability, each being affected by constituents in the component under test. Permeability shifts show on the vertical (x) axis and conductivity on the horizontal (y) axis. Small shifts on the x-axis would be difficult to pick out on a normal running job, but it is suggested that a spot and wave display would assist. A visible electronic gate built around the spot would ensure that it was a simple matter to detect small shifts.

This type of equipment is designed to indicate differences in both permeability and conductivity each being affected by constituents in the component under test. The properties of the testpiece are indicated by the following:

1. Main structural differences—permeability
2. Hardness—conductivity/harmonics
3. Surface stress—permeability
4. Carbon content—permeability
5. Manganese—conductivity
6. Nickel—conductivity/permeability
7. Chromium—conductivity
8. Molybdenum—conductivity
9. Sulphur—conductivity/permeability

Differences in permeability and conductivity are shown in an X-Y relationship. Unfortunately, it is very easy to see permeability shifts on the vertical axis but not so conductivity on the horizontal one.

The obvious answer would be the compilation of a spot and sine wave display. After calibration using the sine wave form, a short run could be made to establish sorting parameters. The display could then be switched to a single spot on a pre-designated part of the now invisible sine wave.

A visible electronic four sided gate would then be built around the spot on the cathode-ray tube. From then on it would be a simple matter to ensure that the spot homes in the gate on satisfactory components under test. This is shown diagrammatically in fig. 8.

Low-frequency bridging systems can be used to obtain satisfactory segregation on most problems concerning cast iron, provided they are used in a
correct manner with adequate known standards. The setting up and operating procedures must be strictly adhered to, as it was possible to generate false information by ignoring certain instructions, such as the proximity of the coils to the unit, to each other, and to other components. Heat and its effects on magnetic fields and large electric motors within four metres of the unit can also influence the apparent read-out. Correct interpretation of this and other information in the supplier’s manual is important to ensure satisfactory results are obtained from what must be considered a useful tool for metallurgical laboratories and iron foundries everywhere.

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