

Computer integrated testing of rod and wire

Eddy current testing provides 100 percent inspection in a fast, simple, cost-effective manner

By Brian Roberts

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Eddy currents have become one of the most widely accepted non destructive test methods used by rod and wire producers. The equipment is relatively simple to install and operate as an in-process inspection tool, providing a much needed production monitoring facility.

Eddy current testing can be applied to both ferrous and non ferrous material, at every stage of the production process. Many of the defects found in ferrous wire can be traced back to corner damage or oscil-

lation marks on the primary billet. The subsequent rolling process can introduce laps or surface damage into the rod. Subsequent drawing operations may produce or exaggerate defects. On non-ferrous material, there may also be problems of tramp ferritic particles or inclusions.

Quality is improved significantly by monitoring and controlling the process at every stage. Defects are usually of a totally random nature, so their occurrence cannot be predicted by SPC methods or random sampling. One hundred percent on-line inspection is needed and recent advances in the use of microprocessors and computers have made automated systems both feasible and practical, even in harsh industrial environments.

This study reviews basic eddy current techniques used in the rod and wire industry and available applied computer technology.

Eddy current basics

Eddy currents are alternating electrical currents of high frequency, which can be induced to flow in any metallic section. See Fig. 1.

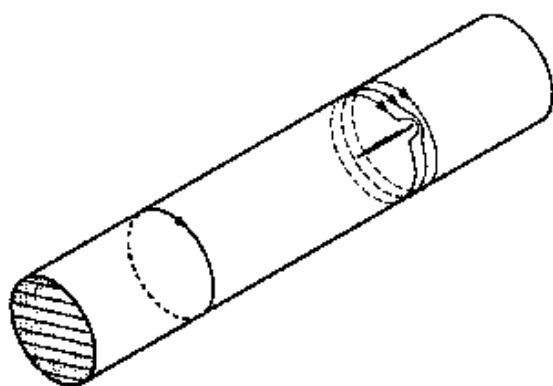


Fig. 1. Eddy current flow patterns

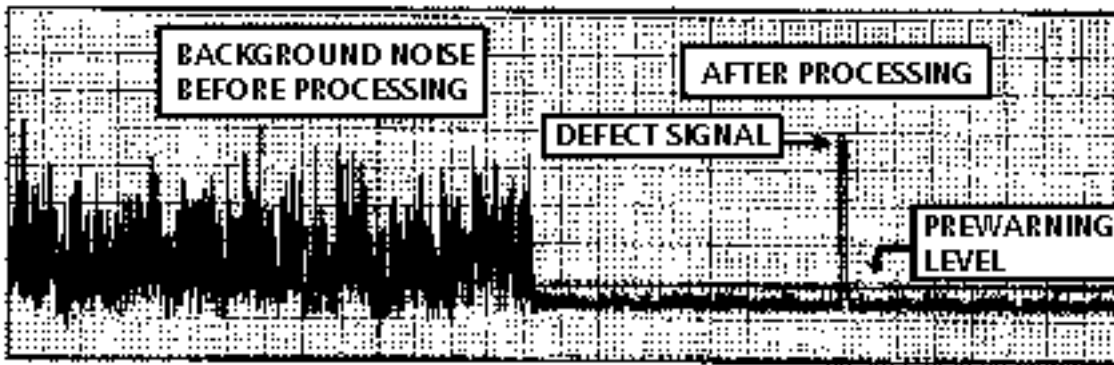


Fig. 2.

The important factor here is "induction," which is an electrical phenomenon whereby energy is transferred from one body to another without any physical contact. This is the basis for transformers, induction heaters and a multitude of other industry equipment.

With eddy current testing, energy is transferred from an electrical coil within the test transducer. Induced currents then flow circumferentially around the material cross section and their distribution is monitored by detection windings within the same transducer. If there is a crack or other discontinuity in the section under review, the eddy current pattern is disturbed and this disturbance is detected, amplified, processed and analysed.

Unfortunately there are other influences which affect the eddy current pattern, notably permeability and resistivity variations resulting from unrelieved stress and chemistry changes. Also, material vibration in the search coil creates large signals. The "state of the art" is to detect defect signals and ignore the spectrum of erroneous noise. See Fig. 2.

This is achieved by advanced transducer and inspection head design, coupled with real-time analysis of signals for amplitude, rate of change and phase relationships.

The advent of inexpensive high speed processors enables this analysis to be carried out digitally at line speeds up to 10,000 m/min where event signals only have a duration of a few micro-seconds.

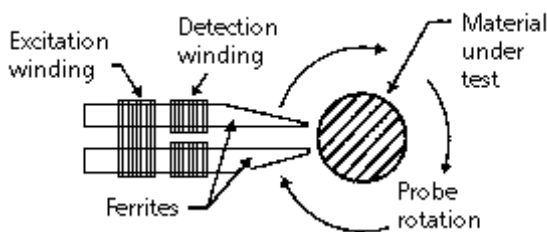
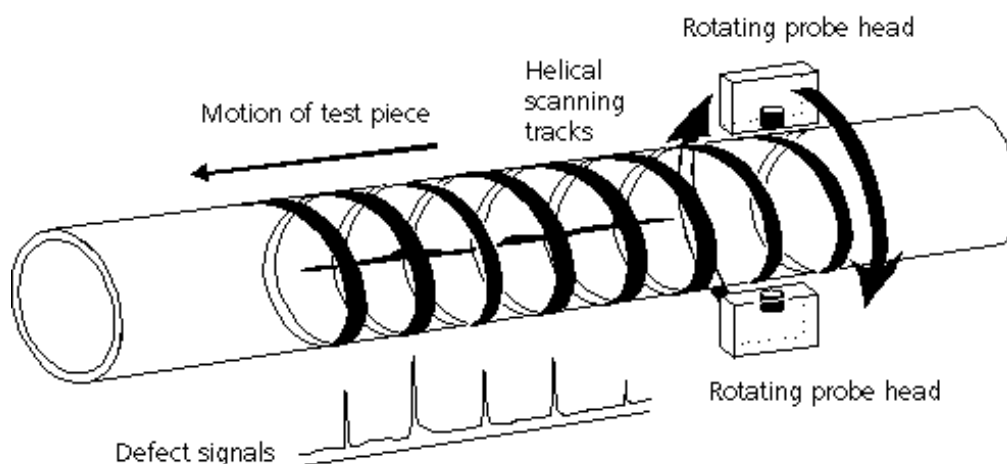


Fig. 3. Rotating eddy current probes

Detection methods

There are just two basic detection methods in common use:

Rotating eddy current probes orbit the wire at high speed. See Fig. 3. Their main purpose is to detect seams and scratch or die marks which extend longi-



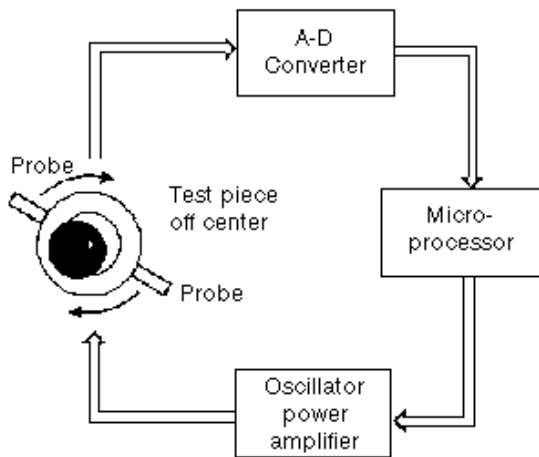


Fig. 4. High speed processors

tudinally along the wire. The probes describe a helical scan pattern relative to the throughput speed of the wire, but 100 % inspection can be assured by adding multiple probes for higher speed applications. Sensitivity is limited to defects at or near the surface.

A significant problem is maintaining a constant gap between the probes and the material, as sensitivity decreases with increase of gap. If our material is slightly off-centre or out-of-round, the gap is constantly changing. Use of high speed processors permits automatic sensing of these gaps with continuous compensation of system sensitivity. See Fig. 4.

Encircling coils, which surround the wire, are wound in a differential or multi-differential configuration. See Fig. 5.

These transducers effectively check the eddy current distribution at one section and compare it with the pattern in the section immediately preceding it. This provides a high sensitivity to a broad spectrum of dynamic defects such as cross-cracks, chevrons, inclusions, pits and natural seams and laps which modulate along their entire length. Score marks which are regular and continuous in width and depth will be missed.

Primary drive current can be much higher in an encircling coil, allowing larger clearances and a greater depth of penetration than with rotating probes. Any tendency toward drift is controlled by a micro-processor-based phase-locked loop to ensure that

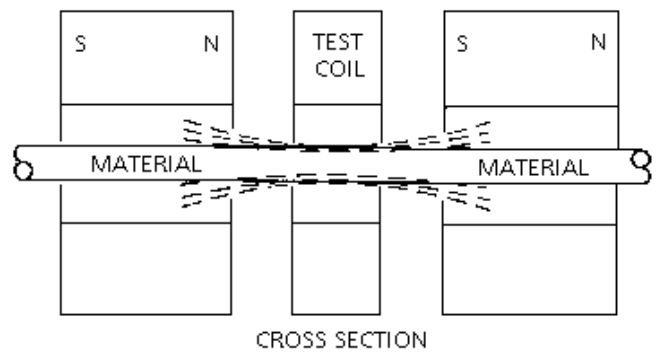


Fig. 6. Magnetic saturation

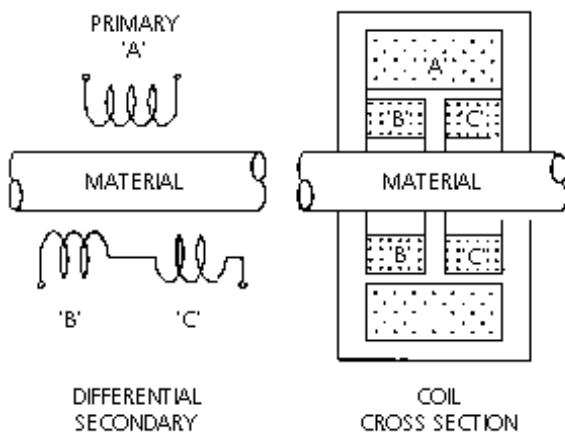


Fig. 5. Differential transformer

the system stays in calibration irrespective of temperature variations and other influences.

When testing ferritic material below the Curie point of 800°C, magnetic saturation is applied to suppress signals, from magnetic variables and enhance sensitivity to sub-surface flaws. See Fig. 6.

Computer integration

Most modern eddy current test equipment is digitally compatible. Signals at the transducer are extremely tiny and of an analog nature but can be converted to digital signals after pre-amplification. In a digital format, control can be left to a computer with the use of suitable interfaces and software. The duties of the computer are multi-fold.

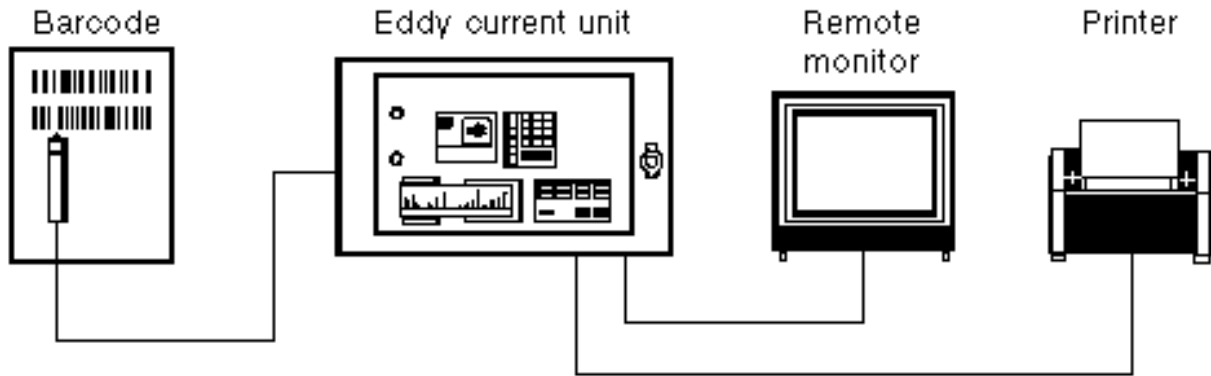


Fig. 7. Barcode parameter setting

Set-up (see Fig. 7). The electronic unit settings can be automatically downloaded from a bar-code, PC or host computer, so that they are optimised for the particular material and diameter or shape to be inspected. Settings include sensitivity, reject levels, speed range, phase vectors and pertinent operating screens. Operating screens can be simplified to increase user friendliness. Monitoring signals are analysed on a real-time basis and a determination made on accept/reject criteria or overall quality assessment of each coil. The system can be continuously checked for operational integrity and malfunctions immediately signalled to the operator.

Stability. Once calibrated, the system is locked-in for years, except for changes in parts or material.

Prewarning. Small changes in background signal can be observed and acted upon if they are continuous or repetitive, indicating a production-related anomaly. Frequently the problem can be corrected before reaching scrap level proportions.

Data storage. Information on every batch of material may be economically and permanently stored on hard drive, diskette or downloaded to the host. Access to historic information is extremely rapid.

Documentation. Reports can be printed giving detailed information on each coil of material (see Fig. 8) or continuous high speed recordings (real-time) are made using dot-matrix printers and heat sensitive (calculator) chart roll paper.

Time coil commenced

"B" level defect 120ft from start, 10ft scrapped

Prewarning to operator 850ft to 970ft along

"A" level flaw (minor) 1790-1800ft (marked but not scrapped)

"B" level defect 2540ft, 10ft scrap

"B" level defect 3460ft, 10ft scrap

"B" level defect 4380ft, 10ft scrap

Printout at end of coil

Time coil completed

Machine operator

Material code, customer I.D., etc.

Actual length tested

Amount scrapped

Amount with minor flaws

Yield for coil

Date	16APR97
Time	10:30
FEET DEFECTS	
100	++B++++++
800	++++!!!!
900	!!!!!!!!++
1700	+++++++A
1800	A+++++++
2500	+++B++++
3400	+++++B+++
4300	+++++++B+
**BATCH REPORT*	
Date:	16APR97
Time:	10:56
Oper.	#040
Lot ID	#81556974
Coil	#7
Run Length	6890 ft
B Length	40 ft
A Length	20 ft
Yield	99.4 %

Fig. 8. Datalog report

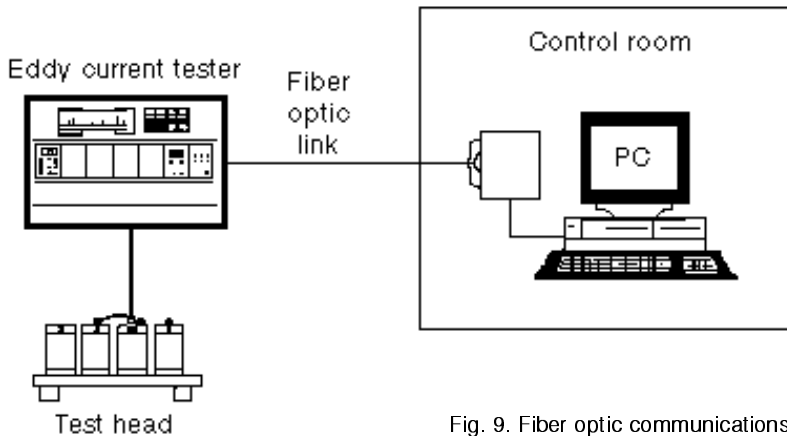


Fig. 9. Fiber optic communications

Remote displays. Monitors can be provided in remote locations for production control or quality control purposes.

Practical considerations

Mill environments are not the most perfect for computers. Industrial computers are available but these need to be housed in an environmental cabinet which is both dust proof and refrigerated. Immunity to electrical interference is good but the cost is high.

One alternative is to use a regular PC such as a 486 or Pentium, and house it in a clean room well away from the mill itself. See Fig. 9.

Communication from the eddy current electronic unit to the PC is made over a four-element, fibre-optic link which can be virtually of any length within the plant. Fibre optics are totally impervious to electrical noise and are routed over long distances without attenuation of signal, which they are carrying. The PC must have auxiliary 16 bit slots so that pertinent signal processing cards can be installed. Remote monitors may be linked up wherever needed.

Displays show the material being currently produced and preceding coils with diagrams depicting defect distribution along each coil with a relative quality assessment (Fig. 10).

The benefits of this technique are demonstrated to perfection in its application on high speed rolling mills. See Fig. 11.

Water-cooled encircling coils are mounted after the final finishing stands to test rod at temperatures in excess of 1,100°C at throughput speeds up to 500 km/hour. Detection electronics are housed in a NEMA12 cabinet adjacent to the inspection head (within 20 meters). Signals are amplified, detected, converted to a digital format and transformed to light impulses which can be fed over the fibre-optic communication links to the PC. Usually the PC is mounted in the pulpit or control room which is a clean air, controlled temperature environment, but a considerable distance away from the electronics. Remote monitors, printers and recorders can be slaved from the PC and placed as and where needed.

Communication with the host or mainframe network is on a file-to-file basis over an Ethernet link. Information is provided on batch number, coil ID, line speeds, coil length, etc. If the host communication is not available, this information can be entered through the PC keyboard, or from a barcode related to each coil.

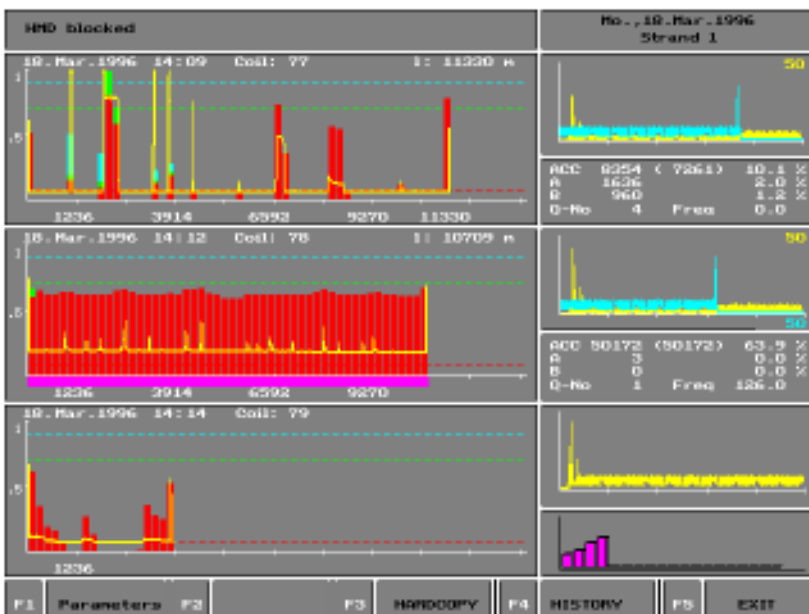


Fig. 10. Rolling mill displays.

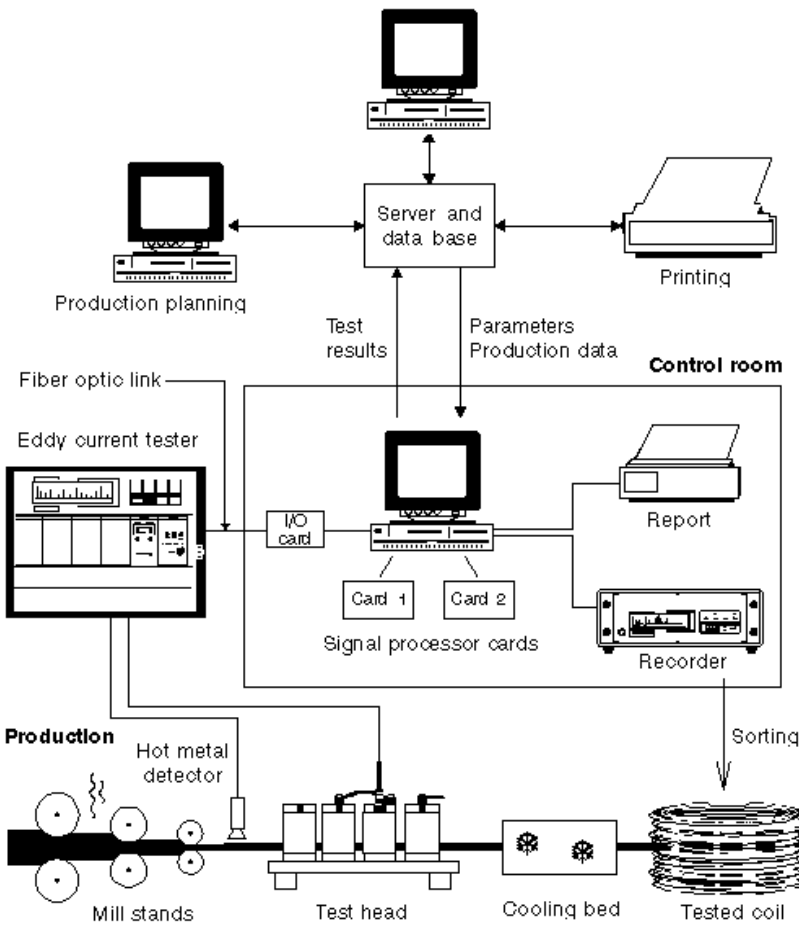


Fig. 11. Host network control

The PC automatically downloads all the electronic parameters of the unit and receives confirmation of these settings and information on detected signals in a digital format. It continuously monitors background signals from the rod and warns if this increases beyond a predetermined threshold for a period of time, or periodic signals are detected indicating damage from the rolling process. The periodicity is analysed and related back to the actual mill stand causing the problem. This can then be translated to a voice message relayed over a paging system.

Defect signals are separately categorised by levels of magnitude. At the end of each coil, a quality status is established based on the number and distribution of flaws along the length. Complete summary reports are generated, displayed, printed and stored.

It is impossible to mark or segregate defects at this stage, but scrap is reduced by the production monitoring facility.

Other applications

Similar, less complex, systems are developed for wire drawing operations, oil tempering lines and cold heading or coiling machines.

For wire drawing, inspection usually takes place between the die and the bull blocks (see Fig. 12) or within the straightening operation. Defects can be marked or registered with respect to their amplitude and location along the coil. Oil tempering usually involves multiple strands side by side. Individual inspection heads

are located on each strand but the electronics and PC are common shared units to reduce overall cost. See Fig. 13. In the heading and spring making applications, inspection takes place on the wire following straightening. Defects are accurately tracked by the machine PC or a microprocessor-based shift register, to initiate automatic sorting of the contaminated part after the crop operation. Double wound encircling coils are available to overcome problems associated with the stop/start feed on these machines. See Fig.14

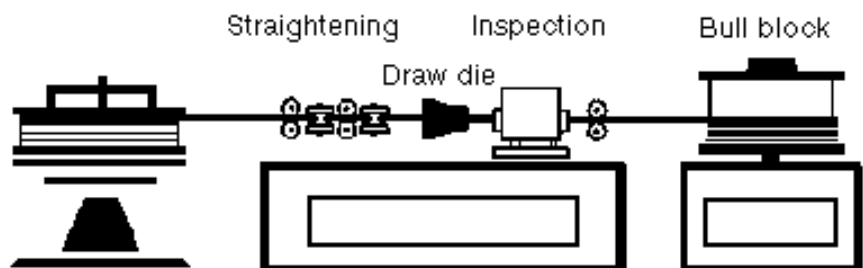


Fig. 12. Inspection between die and bull block

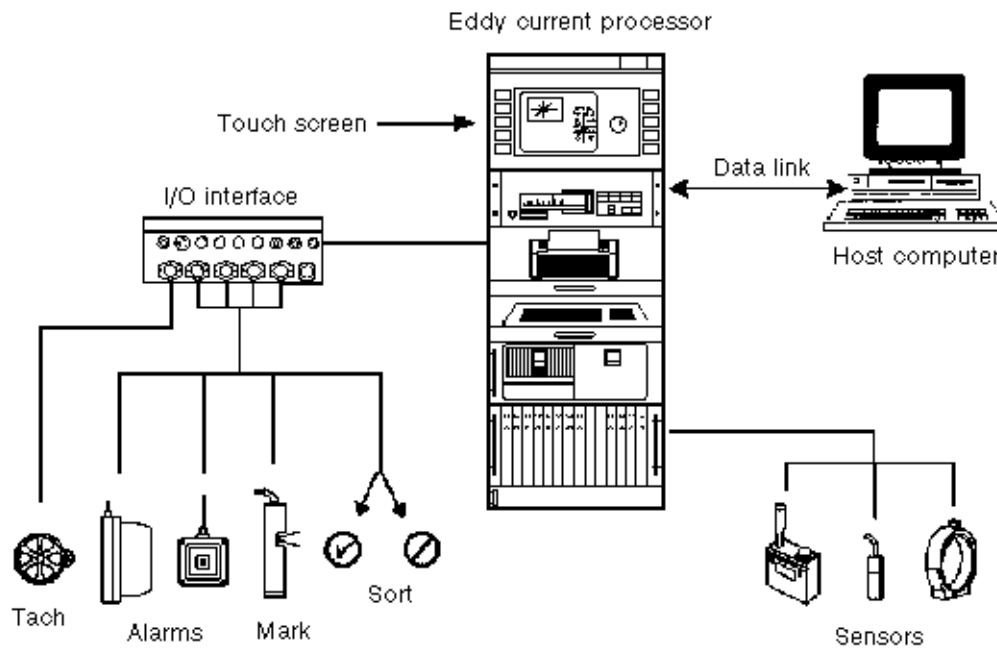


Fig. 13. Multi-strand inspection

Conclusions

Advantages of in-process testing:

- Fast: Test speeds up to 10,000 m/min;
- Simple: no need for skilled technicians;
- Non-contact: no wear, adequate clearances;
- Valid test: sensitivity to a broad spectrum of defects and irregularities;
- 100 percent inspection: random flaws cannot be detected on a statistical basis;

- Cost effective: improved QCA without increase in production costs;
- Automatic: little or no operator supervision required;
- Direct reaction: eliminate problems as soon as they occur;
- Documentation: proof of test;
- Mastering: computer initiated, controlled, and corrected and supervised;
- In-line: a real aid to production efficiency.

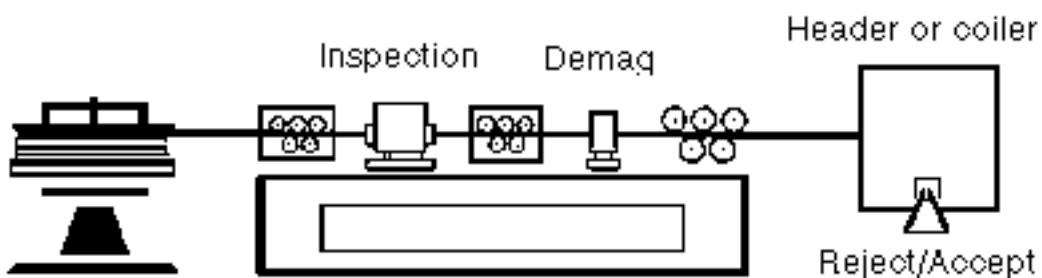


Fig. 14. Cold heading or spring making application