CASE STUDY

Real-Time Eddy Current NDT in a Hot Rolling Mill

Dual phase analysis supports the feasible of relatively low frequency eddy current testing

BACKGROUND

TÜV Rheinland Industrial Solutions, Inc. (TRIS) conducted a dual phase feasibility study for the detection of micron sized (≥ 50μ) inclusions in rolled milled steel material with a nominal thickness of 0.035”. The purpose of this study was to determine if a real-time nondestructive testing method (PSEC) could be applied that would lend itself to in-situ testing conditions that exist in a hot rolling mill. After a preliminary evaluation it was demonstrated that a low frequency eddy current technique applied to magnetically saturated ferrous material might provide real-time, in-process data. The laboratory testing provide useful metrics for monitoring the distribution, relative quantity and size of naturally occurring inclusions resulting from a hot mill process for relatively thin rolled material. The attributes of low frequency eddy current testing most attractive was the ability to acquire volumetric data metrics by surface scanning of magnetically saturated material moving at high linear speed with high-speed data analysis.

BUSINESS CHALLENGE

In approaching this task, it was determined that two test elements (dual phase) would be needed to support the study process. The first challenge was to nondestructively find, identify and locate anomalous indications that might be contained in sample material as would be representative of a less dense that base material, inclusion. The second challenge was to demonstrate a surface-scan eddy current (partial saturation) technique that could reasonable match, with reproducible results, the detection of the radiographically identified inclusions.

In order to meet the first challenge, micro-radiographic as the volumetric testing method was selected. Although microradiography is not considered a typical routine industrial test method, it has become increasing used in recent years for nondestructive testing of small electronic components (both 2D & 3D) for the defense and aerospace industry and for 3D evaluation of specialty castings and unique composite and metallic components. It’s application in the medical community is well known.

There are several OEM’s of micro-radiographic systems available today and in use for industrial applications. The First Phase for the evaluation of samples (nominal size of 12”x14”x 0.035”) was to use the micro-radiography technique with a sensitivity and resolution capable of identifying micron-sized indications in the base metal matrix and mapping the X-Y locations. Material samples were selected at random from a single “run” of sheet material and a visual surface inspection was performed to identify and catalog surface indications. The six samples were radiographed using a Nikon Model XTV 160 x-ray inspection system with an effective x-ray focal spot of 0.0000394”. The two-dimensional digital imaging method used an image intensifier with a pixel resolution of 4000 /in2. In typical radiographic context, the image unsharpness and detail sensitivity was more than sufficient to resolve indications of 50 μ or greater. The radiographic test results presented images with measured sizes of identified inclusions ranged from ~ 40 μ to 120 μ in profile. Tje x=ray image produced progressive and subsequently X-Y indexed images, each image of a 0.1” x 0.1” area. Each sample received a 100% scan.

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BUSINESS CHALLENGE CONTINUED

The resultant images were captured in JPEG format for image the purpose of image interpretations and analysis. Typical radiographic images with a representative indication are shown in Figures 1A & B. One must keep in mind that the image processing with the Nikon Model XTV 160 x-ray inspection system produces an image with reverse density contrast, e.g., lighter-appearing inclusions are representative of LESS dense regions than the base material.

The images were evaluated for all six samples, representing in excess of 20,000 individual images, and a single representative sample (referenced herein as the “master” sample) that exhibited typical and multiple sized inclusion type indications was selected for further testing. All of the identified indications within the single sample were recorded with the X-Y coordinates as given by the image identification index. In order to provide a zero reference location on the sample plate, the plates were marked with an indent on a corner to represent the X0-Y0 location. Each image was digitally recorded by the computerized Nikon system and indexed from the zero reference marks in increments of 0.1”. The Second Phase of the evaluation was to determine the feasibility of detection of the indications found with Micro-Radiography using low frequency eddy current testing coupled with a saturated magnetic field. Eddy current testing was performed using low frequency eddy current testing coupled with a saturated magnetic field. Eddy current testing was performed using a Pruftechnik 5 system and Pruftechnik eddy current probes. Data capture and analysis was performed by Pruftechnik Eddytrend Windows-based software via IPC LAN connection to the Pruftechnik 5 system for delivery of real-time data display, data management and storage.

This system was selected due to its advanced computer-based software system and extensive signal evaluation options. Consideration was made in selecting an eddy current system that was ideally suited to operate in a hot mill environment on a production line with a remote Windows PC or central operator panel as an integral part of a process control system as might be required for in-situ testing in a rolling mill with a Wonderware software end-user application.

In order to perform the eddy current testing on the samples (sections of actually rolled material) a fixture was fabricated that would compress the rolled (slight curvature), see Sample Test Plate in Figure 2, samples and provide a flat surface for surface scanning. The fixture included an eddy current probe holder, probe-proximity and adjustable permanent magnet coil mounts, and an x-y scanning guide frame that allowed for X-Y indexed scans of the plate sample. The Pruftechnik eddy current test equipment and the test fixture are shown in Figure 2. Repeated eddy current testing (scans) was performed on the “master sample” for a known lengthwise 1” width by 12” length section of the sample for which there were nine radiographically recorded individual indications ranging in size from ~ 40 to 100 microns in nominal diameter. This region of the master sample was selected since the adjacent area on either side of the 1” strip was relatively free of other radiographic identified indications and surface indications. Multiple

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scans were performed at various instrumentation settings until a clear set of return eddy current signals were recorded. The resulting eddy current critical test parameters with and without a superimposed, computer generated were for the frequency set for 30 kHz with an instrumentation gain of 43-50db. The total scan length for eddy current test results were matched to the radiographic identified indications for the nine internal inclusions contained in the 1" wide and 11" length.

In Figure 3 above, the results of the image vs comparative eddy current data are shown. The single image frame represents one identified inclusion within the 0.1" x 0.1" area of the sample. The scans represent two separate scans of a 1" wide strip containing multiple indications (inclusions), as represented by the inclusion presented in the image. A correlation was made based on the actual location of the of the indication in the sample, and the single "peak" recorded as typical for that indication as noted in Figure 3. There were a total of nine similar inclusions contained in the 1.0" wide strip of the ~ 12.0" of scan length.

Confirming scans were made of the calibration test sample to confirm that the eddy current test parameters would produce a signal response from the three flat bottom drilled holes when the test sample was tested from the opposing side of the sample plate containing the flat bottom indications. Extensive testing was performed on the "master sample" and whereas the data was consistent, not all of the radiographically recorded indications were detected by the eddy current testing. Based on the number of repeated scans performed in both the X and Y direction, we determined that approximately 80% of the "known" locations for internal indications produced a concise and noted eddy current response signal.

In summary, the dual phase analysis supports the feasible of relatively low frequency eddy current testing using a saturated magnetic material allowing the detection of the micron sized internal Indications (inclusions) in the material. In addition, further testing was performed with equally reproducible results at increased scanning speed and with the eddy current signal becoming more distinct with increases in scan speed. Whereas the test did not approximate the 600fpm of actual linear speed as would be seen in production the EDDYCHECK 5 compact system is used successfully in other applications in wire drawing operations where the speed has been measured at up to 18,000fpm. Further testing is recommended and should be followed by physical metallographic examination to characterize the type and nature of the indications identified by the micro radiographic method and correspondingly characterized by the eddy current testing.

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