Automatic Defect Recognition in MPI - Inland Steel Research Project

A Paper By

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INLAND STEEL VISION RESEARCH PROJECT

1 Background

The background to this project is to expand on work that Insight NDT had previously completed, which resulted in the technical paper Automatic Defect Recognition in Magnetic Particle Inspection Applications.

In this paper we concluded that for Web inspection applications, it would be advantageous to use a TDI (Time Delay Integration) Line Scan Camera instead of a conventional Area Scan Camera. A web inspection application is an application where the product to be inspected is passing in front of the camera at relatively high speeds, such as the use of a Vision System to detect MPI indications on a steel billet as the billet moves by.

2 System Design

The principle of all systems that inspect or image moving objects is to achieve a stop action within the resolution of the smallest indication that you wish to detect. Up to now two methods have been used which are a Laser Scanning System and a Strobed Image Capture with a CCD Camera.

Laser Scanning has been used effectively at low speeds, despite its relatively high cost. But at high speeds it suffers from a number of technical limitations. Typically scan rate, spot size and dynamic range. With a scan rate of 5000 scans per second on a 60in image moving at 60 in/sec 12.5 percent of the scanned image is not recorded.

The second method uses a CCD Camera. An area scan camera can be used by strobing the light of the same frequency as the stop action desired. A better CCD method is to use a line scan camera in which the lines are outputted at the same rate as the stop action required. The line scan camera is the superior method since it is continuously exposed to the light and at a higher resolution capability than the area scan camera.

The basic flaw of both CCD systems is that they do not make optimum use of the two most important parameters in high-speed imaging: time and energy. By strobing light by laser scanning or flash lamp, you introduce a duty cycle, which will always be less than 100 percent. Therefore, the light, when it is present, must have relatively more power. This creates added cost for lamps and controllers besides reducing reliability through lamp life.

The high-speed inspection problem can be reduced down to the availability of two parameters: energy and time. The output signal is directly related to the number of photons incident on the photo element. When an object passes over a sensor at high speed, the integration time in which to collect photons is reduced. This means that higher and higher powers of light are required to achieve the same signal as at lower speeds. The other problem associated with the short time is the need to process the video data in real time.

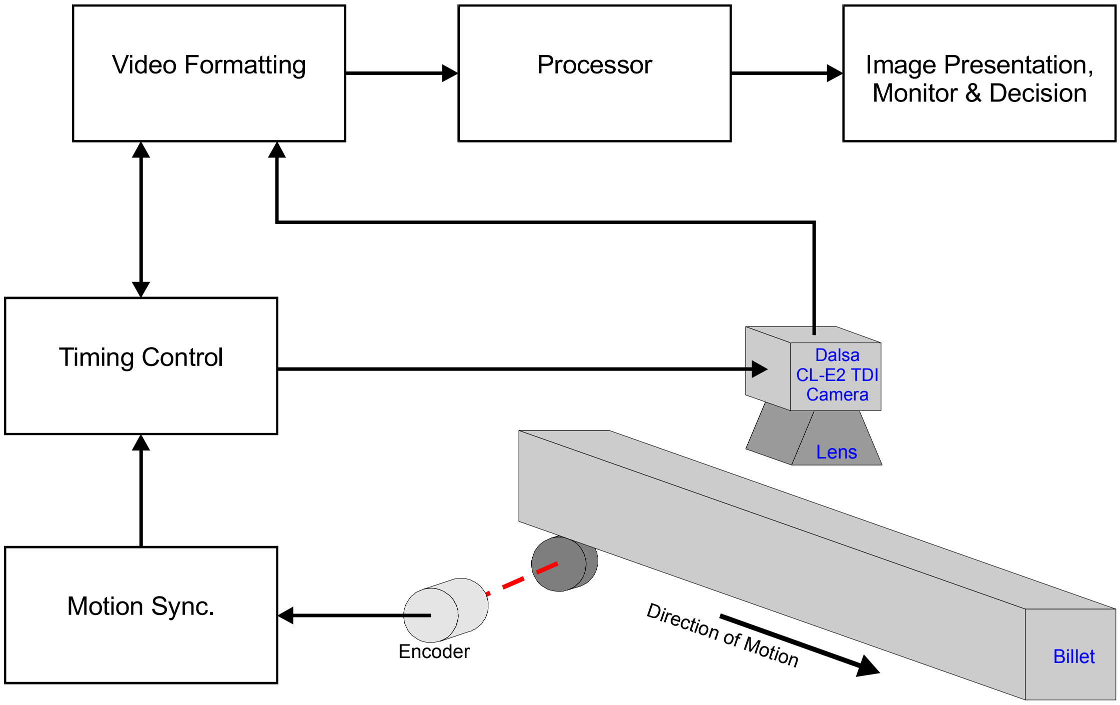
If you imagine that you are travelling in a car on the highway and you see a small object on the road in front of the car. You can't see it because your eyes don't have enough time to sense the reflected light. But now consider how much easier it would be if the object was also moving at slow speed. This would keep the object in our sight longer, permitting both longer light collection time and longer analysis time. This is the basic principal of TDI or Time Delay Integration. It makes use of synchronous motion to take multiple pictures of the same image and add them up to get an amplified image.

TDI is the name given to this method of combining many individual rows of line scans together in order to increase the total ability to sense light. It would be impossible to explain the TDI Sensor operation in this paper.

3 Equipment

To further investigate the application of machine vision to the MPI Billet System, a simple test system was designed. The aim of this system was to be able to transport the samples of billet across in front of a camera, and capture resulting images.

The layout of our test system is shown below. The speed of the test sample to be imaged is monitored and synchronization is determined by this speed. A timing control unit generates the necessary camera clock signals as determined by the encoder attached to the test sample transport mechanism. Video from the camera is stored as formatted video before processing begins. Processing of the image can then be accomplished before presentation to the user.



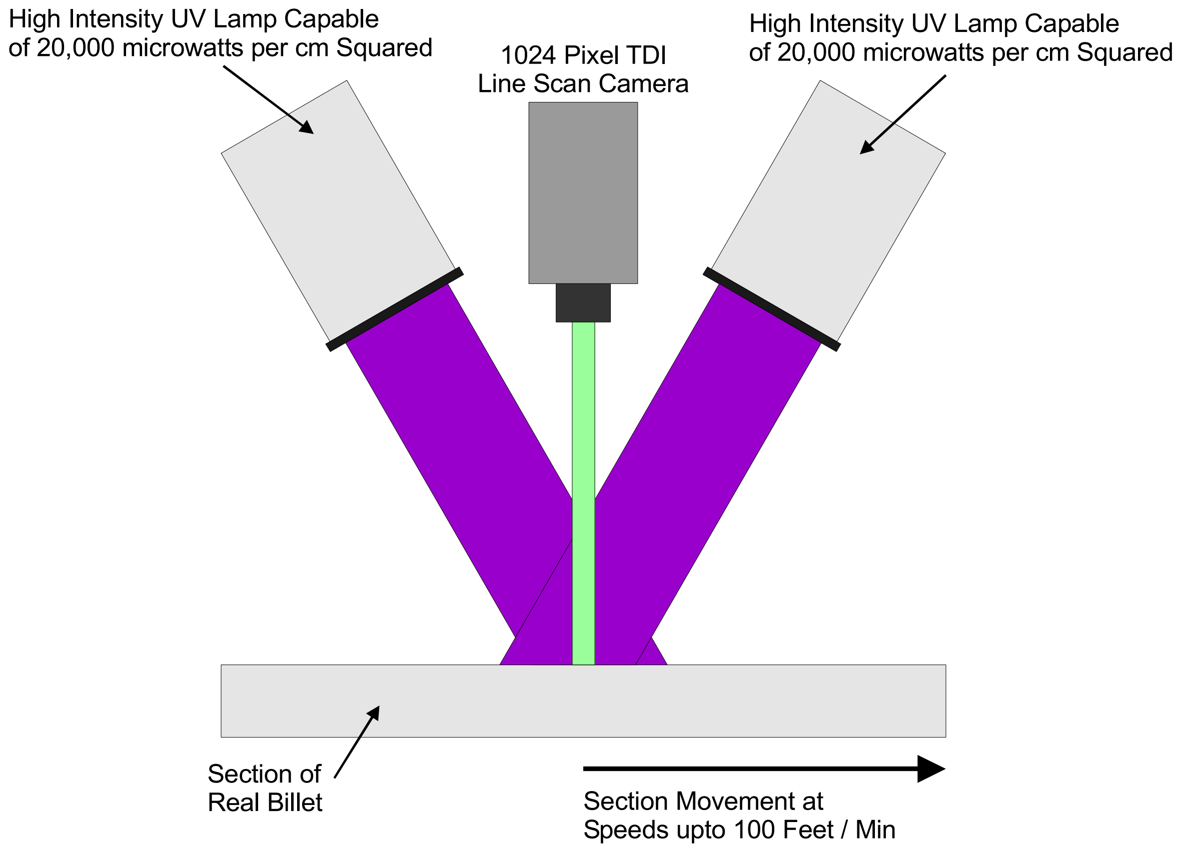
To illustrate the typical performance for a TDI System, an image was captured by a frame grabber and displayed on a monitor. This image is shown below and is the actual size of the document scanned. It should be noted that the zero in “500” is 39.4 thou (1mm) wide. Scanned at a speed of 240ft/min, the “500” is shown in the centre image below. The width of the line above the “500” is 1 pixel. The resolution of the camera is so fine that the output appears as a staircase pattern. The line width of the zero corresponds to a single photo element on the image sensor.

The uniformity of the image shows that the synchronisation that has been achieved is accurate to less than 1 pixel. For the camera used, 96 stages of 13um indicate a no vibration interval of 51.2 thou (1.3mm), which can be achieved relatively easily.

A simple drive system was selected that would allow the sample of billet to be transported at speeds up to 100 feet per minute. (508mm per second). The camera selected for this web application is a Dalsa TDI Line Scan Camera. The concept behind the TDI Camera is outlined in our technical paper ‘Automatic Defect Recognition in Magnetic Particle Applications’.

The camera selected was the Dalsa CL-E2, which has a horizontal resolution of 1024 pixels. The test piece was illuminated by two Labino UV Spot lamps, each of these lamps are capable of illuminating the scan area at an Irradiance of greater than 20,000 uW/CM^2 at a distance of 39" (1000mm) from the test piece itself.

The general arrangement for the test system is shown below:



The camera was mounted at a distance of 22" (558.8mm) from the test piece. However, the system was designed such that this distance could be changed if required. A 25mm F1.4 lens was fitted to the Dalsa Camera, which at this distance gives an effective field of view at 11.25" (285.75mm).

Connection of the camera, to the PC is via Image Acquisition hardware, normally known as a frame grabber. For this system a frame grabber from National Instruments was selected. The reason for this is that we intended using the IMAQ Vision Software also supplied by National Instruments.

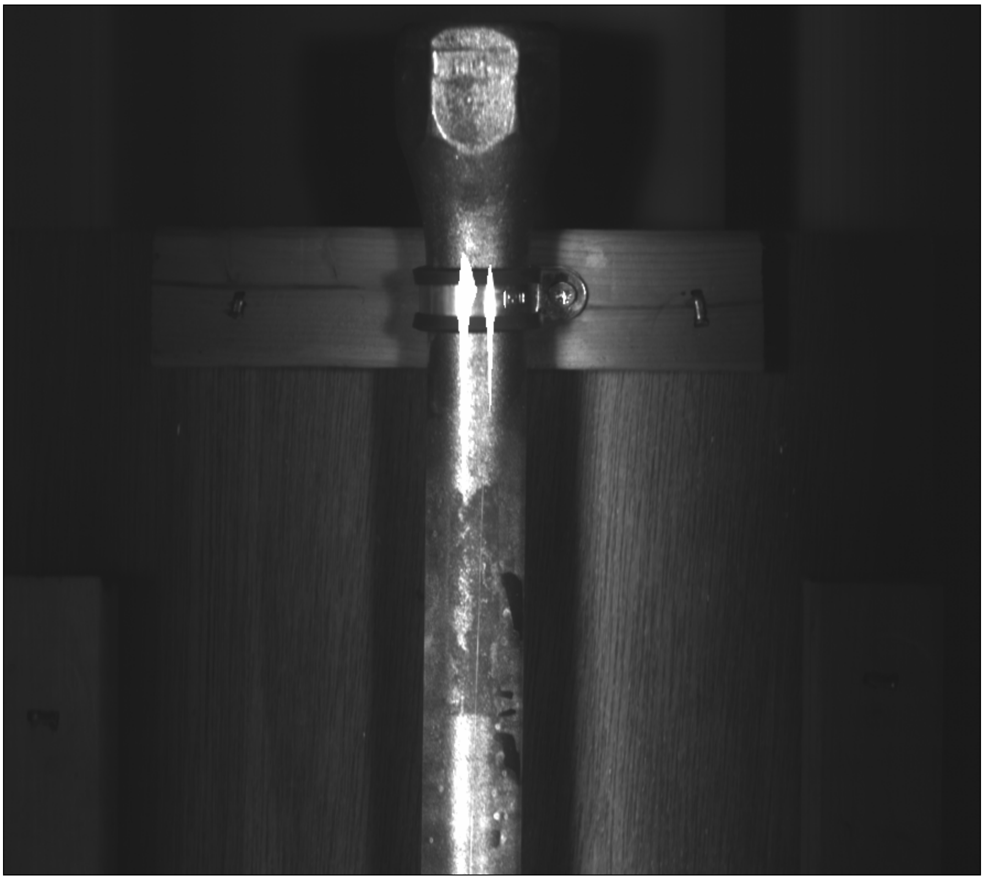
The IMAQ Software package is an enhancement on the standard Labview software, which allows simple and quick customisation of the final software, for this system. Another unique feature of the IMAQ software is that is has a large number of standard image processing functions that allows us to investigate the processing of the captured images, to detect and size the defects found.

4 Tests Completed

In order to check that the Vision Test System was functioning correctly the test platform was illuminated using two conventional reflector type 100W white lights. The wooden test platform was scanned using the TDI Camera. The platform was moved at an approximate speed of 20in/sec (508mm/sec). The resultant image is shown below. It should be remembered, when considering the quality of the image that we are somewhat limited by the printer and the printing. It is suggested that the electronic version of this document is examined.

You can see that the TDI Camera is clearly picking up the grain structure of the wooden platform. Also the heads of the counter sunk socket head screws can be seen. The horizontal and vertical line was drawn on as a reference and was approximately 0.079“ (2mm) wide.

Having established that the Vision System was working correctly we move to the black light inspection. We started with the same component used previously. This was to establish a base reference for the system. Since we knew that this particular component had a longitudinal defect very similar in nature to a longitudinal seam defect in a steel billet. The image captured from this component, under black light is shown on the next page.



It is possible to determine the defect from this image, which was found to be very promising since the seam was completed at 20in/sec (508mm/sec) and a field of view of over 11in. On the basis of the results obtained from this component the three HMS test samples we magnetised and view to see the nature of the defects within them.

According to our records these test samples had the following defects:

1. HMS – Heavy Scratch
2. HMS – Seams
3. HMS – Crack / Seam

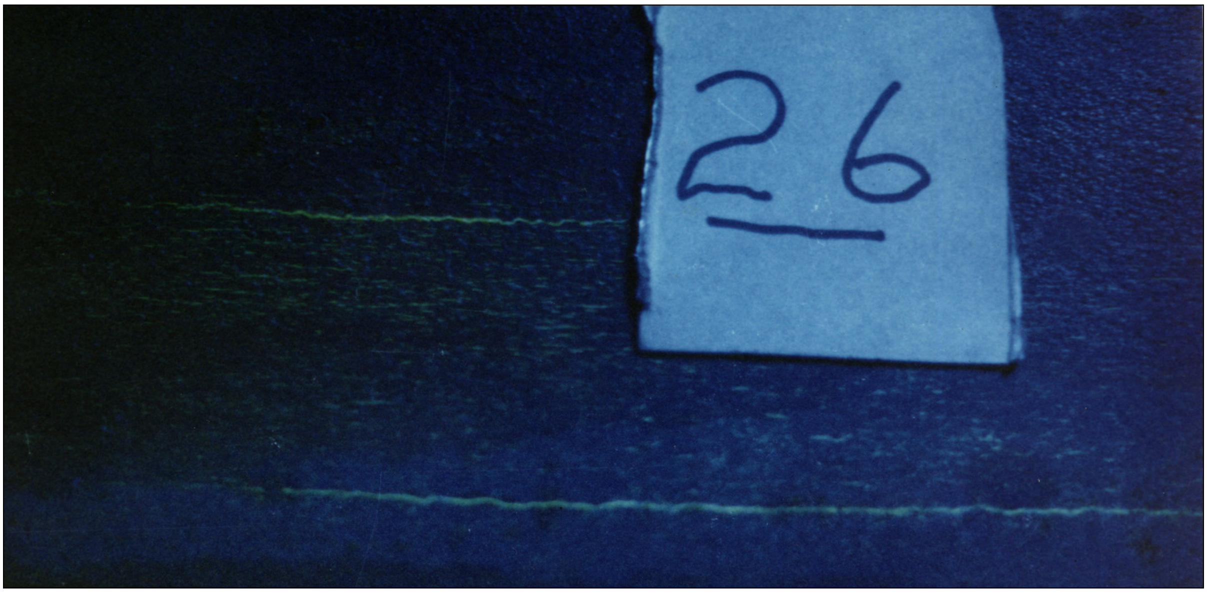
At this time the CMS billets were not considered since currently the CMS product does not go through the MPI process.

From our visual inspection of these test pieces we concluded that these samples did not represent a fair test of any vision system because it was very difficult to determine the defects just by our visual check. The heavy scratch would not show an MPI indication since it was too wide for an indication to form. All that would happen is an effective pooling of the indicating fluid in the scratch.

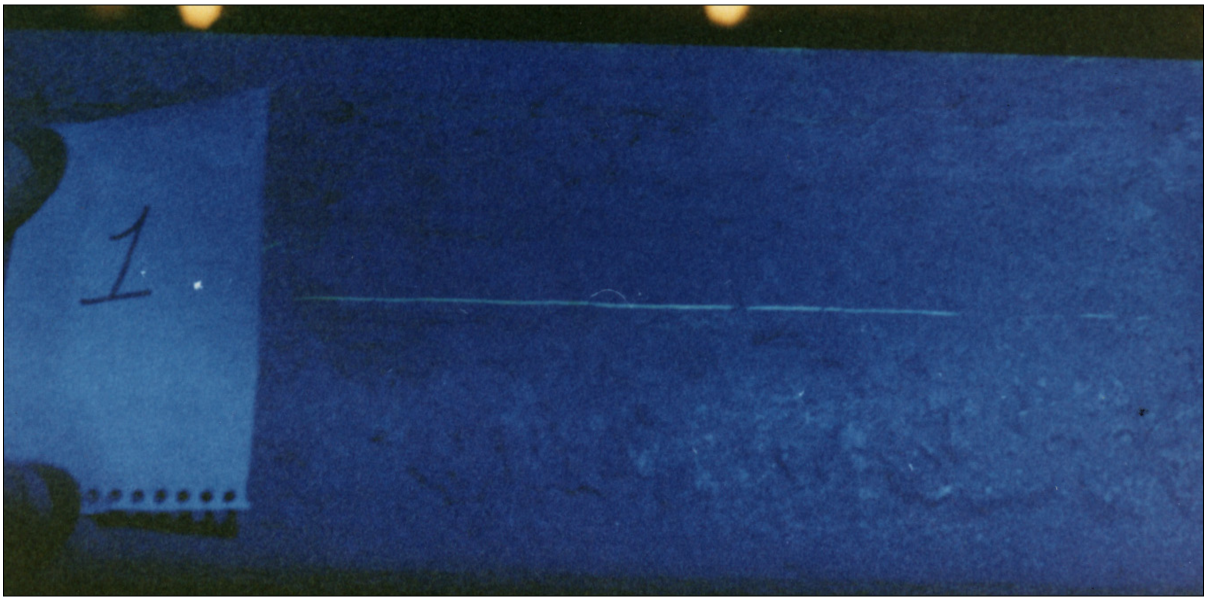
On the above two samples no real meaningful defects were found. For the purposes of testing the viability and sensitivity of this test vision system, it would have been better to have test samples that had more obvious defects and then once these defects were being detected then look at the sensitivity of the system.

From the information we currently have and the experiments that have been completed during this project we are confident that the system as is would detect the defects shown in the following illustrations.

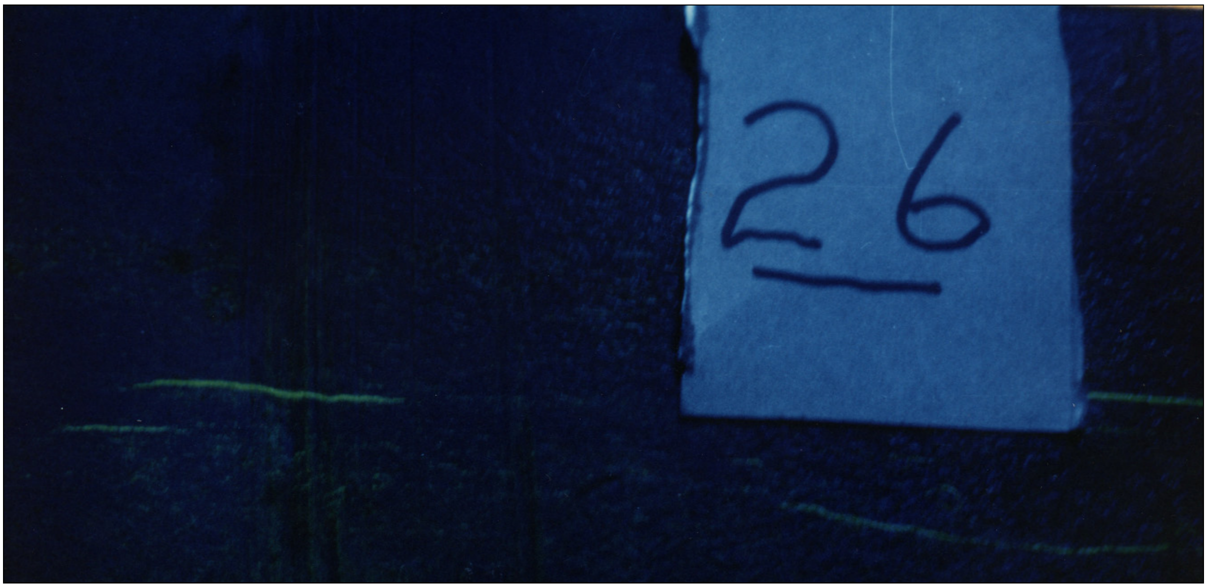
4.1 Straight Laps



4.2 Longitudinal Seams



4.3 Short and Arc Laps



5 Conclusions

From the work that we have performed thus far we are of the opinion that a Vision System for the Black Light Inspection is technically possible and reliable at inspection speeds up to 20 in/sec (508 mm/sec)

Realistically the next step is to put a single camera system into service for an extended period of time, to provide its production viability.