AUTOMATIC DEFECT RECOGNITION (ADR) SYSTEM FOR REAL TIME RADIOSCOPY (RTR) OF STRAIGHT TUBE BUTT (STB) WELDS

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ABSTRACT

Non Destructive Evaluation (NDE) Methods, in particular Digital Radiography (DR), incorporated with Automatic Defect Recognition (ADR), for industrial applications is a rapidly progressing area of research across the globe. Though ADR technology has been well established for Digital Radiographic inspection of cast and machined components, ADR is still considered a challenge in the case of many types of weld joints, mainly due to the non-uniformity in the radiographic images of weld joints. This paper introduces an indigenously developed Automatic Defect Recognition System for Real Time Radioscopy (RTR) of Straight Tube Butt Weld (STBW) joints, which are the critical joints of tubular components like Economiser, Super heater and Reheater of a Boiler. RTR system for inspection of STB welds consists of a constant potential X-Ray equipment with swiveling arrangement, as the X-Ray source, Digital Flat Panel (DFP) as the Imaging device with its associated Image acquisition and Review Software, along with the ADR software for Defect recognition, classification and thereby evaluation of STB welds. ADR Algorithm, scans through the Digital X-Ray image of the STB Weld joint, and detects the defects present and takes the decision of Acceptance / Rejection, based on the Acceptance Standards for STB welds. Artificial Neural Network (ANN) techniques enable the Algorithm, continuously learn and evolve as a more efficient program, with each joint it evaluates. This will enhance the reliability of defect detection and evaluation. The preprocessing uses concepts from digital image processing, image analysis, and pattern recognition. The development of this system involved validation with a wide range of weld samples with various types of discontinuities. The system has been implemented in one of the RTR stations in BHEL and the ANN training has so far resulted in over 95% accuracy level. This system replaces the hitherto used, humane evaluation and removes its inherent limitations like subjectivity, inconsistency, fatigue etc and accomplishes a faster and more reliable evaluation.

Keywords: Automatic Defect Recognition, Real Time Radioscopy, Digital Radiography, Digital Image Processing, Pattern Recognition, Artificial Neural Network, Radial Basis Function.

INTRODUCTION

Radiography is very well established as an NDT technique, using both film and electronic X-Ray detection systems. Mainly used in the petroleum, petrochemical, nuclear and power generation industries especially, for the inspection of welds, the radiography has played an important role in the quality assurance of the piece or component, in conformity with the requirements of the standards, specifications and codes of manufacturing. Most radiographic exposures and film interpretations in RT are still carried out manually (1). Human interpretation of weld defects, however, is tedious, subjective and is dependent upon the experience and knowledge of the inspector (2). Human inspectors are not always consistent and effective evaluators of products because inspection tasks are monotonous and exhausting. It has been reported that human visual inspection is at best 80% effective. In addition, achieving human ‘100%-inspection’, where it is necessary to check every product thoroughly, typically requires high level of redundancy, thus increasing the cost and time for inspection (3). Here comes the importance of Automation of evaluation, which reduces human involvement, thus making the inspection more reliable and faster.

REAL TIME RADIOSCOPY (RTR) OF STB WELDS

Tubular products form an important part of Steam Generators in thermal power plants. These include mainly Super heater, Reheater, Economizer coils, water wall panels etc. These components consist of tube assembly of several meters length and the required length is achieved by Straight Tube Butt (STB) welding process. These tubes are made of carbon steel, alloy steel etc. It is a pulsed Metal Inert Gas welding process using spray type of metal transfer both at average current levels and low current levels which are very much suitable for out of position welding and thin gauge material welding. The major
defects which occur in this weld are Porosity, Gas hole, incomplete penetration, Lack of fusion, Excess penetration, Burn through, etc.

STB weld joints are subjected to online monitoring system for quality assessment. This system is called Real Time Radioscopy system (RTR). These systems consist constant potential dual focal (large focal size 3 mm x 3 mm and small focus 0.8x 0.8 mm) X-Ray machine with capacity 320kV, 10mA as the X-Ray source and Digital Flat Panel Detector (FPD) as the Imaging device. X-Rays from the source penetrate through the weld thickness and the differential absorption of radiation gives a two dimensional X-Ray image of the weld joints. Incoming X-rays first strike a Cesium Iodide scintillator of the Digital Flat Panel, which converts the X-Rays into light. The light then passes through a photodiode matrix of amorphous silicon, and get converted to electrical signals, which are amplified and digitized. The light is directed onto the silicon without lateral diffusion, which ensures image sharpness. The digital data is then processed into images via a corresponding gray value table, and is displayed, printed or sent to computer as required. The system offers the additional advantages of image post-processing and archiving. Compared to other imaging devices FPD provides high quality digital images, better signal to noise ratio and dynamic range of 12 to 16 bit, which provides high sensitivity for radiographic application. The present RTR system in BHEL uses an Amorphous Silicon Flat Panel (model: DXR250RT). The Images obtained by Flat Panel Image Acquisition and Review computers are in DICONDE format.

These images are evaluated by experienced, qualified NDE personnel, decision of acceptance /rejection taken as per standards and the feedback is given to the welder. The thickness range usually is 4 mm to 12 mm. The Radiographic technique used here is Double Wall Double Image.

**AUTOMATIC DEFECT RECOGNITION (ADR) OF STB WELDS**

The manual evaluation has certain limitations like subjectivity, and humane dependency, which affect the productivity and reliability. Here comes the importance of Automation in evaluation, which reduces human involvement, thus making the inspection more reliable and faster. The ADR system scans through the Digital X-Ray Image of the STB weld joint, and recognizes the defects and takes the decision of Acceptance / Rejection, based on the Acceptance Standards. ADR technology is already available for Castings especially Aluminium Wheels, Magnesium components and weld joints. There are also ADR systems available for general applications.
NDT methods (12). However, there is no customized package available as such, for ADR of Straight Tube Butt welds. This triggered the development of an ADR system for integrity assessment of STB welds. The new system is different from other ADR systems in the aspect that, it uses different detection approaches for different class of defects where as many of the other ADR systems do defect classification only after defect detection.

ADR ALGORITHM (13-19)

The first stage of operations performed by ADR algorithm is preprocessing of the input image. This stage involves enhancement of the image properties to such a level that, the pattern recognition can be executed without errors. In the case of the STB weld image, the Region of Interest (ROI) includes the elliptical weld region and adjacent raw material region of joining tubes. The next step is the extraction of the ROI, by finding it’s boundaries by analyzing the vertical summation of the extracted tube for regions of heightened activity.

<table>
<thead>
<tr>
<th>Type</th>
<th>No of test samples</th>
<th>No of Classifications</th>
<th>Correct Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category I (Gas Hole &amp; Pores)</td>
<td>560</td>
<td>546</td>
<td>97.5%</td>
</tr>
<tr>
<td>Category II (ICP &amp; LF)</td>
<td>95</td>
<td>92</td>
<td>96.8%</td>
</tr>
<tr>
<td>Category III (Burn Through &amp; Excess Penetration)</td>
<td>100</td>
<td>85</td>
<td>85%</td>
</tr>
<tr>
<td>Non defective joints</td>
<td>840</td>
<td>823</td>
<td>98%</td>
</tr>
</tbody>
</table>

The code was tested initially on a set of 1500 weld image samples. These welds include non defective as well as defective weld joints covering a wide range of defects of different size, shape, location and orientations. The results of the trial are shown in table 1. Defect recognition algorithm based on RBF can efficiently overcome the shortcomings of traditional methods, which require large number of samples.

Fig. 5: Input image before & after contrast enhancement, ROI extracted from contrast enhanced image

Fig. 6: ROI extracted images of welds with BT, GH and ICP respectively, Binary image of ICP feature extraction
CONCLUSIONS AND SUMMARY

Usually the approach for common ADR algorithm is the recognition of the defect, followed by classification based on the features. However this Algorithm applies different techniques for detection of different classes of defects and hence defect detection and classification are parallel processes. The trials carried out gives good results for class I (Gas hole and porosity) and class II (ICP and LF). However the performance needs to be improved in the case of the third category. ANN training with sufficient quantity of images is being carried out to enhance the detection level further. Application of other networks like support vector machine (SVM) is also being studied so that probability of detection of class III can be enhanced. In the case of training samples, the size of the sample with one class of defect should also take in to account the probability of occurrence of that class during actual field trial. It is also important to note that RTR offers real time image and by rotation of the tube and swiveling, different images of the same weld joint can be captured. Some defects which are not prominent in one image become prominent in a different orientation of the weld with respect to the source and detector. Hence a defect detection approach based on multi image or direct frame analysis of a video image can enhance the detection and classification level significantly.

Fig. 7 : ADR GUI during normal operation

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