Ultrasonic NDT technique for detection of creep damage in welded steel pipes

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Abstract

The welds of the steel pipes operating under high temperatures and pressure can be affected by creep damage which usually occurs in heat affected zones. The creep damage starts to develop from creep cavities possessing dimensions of a few micrometres, which are growing in time. In the later stages of development, the creep originated cracks are relatively easy detectable. In this case, due to the expected fast grow of cracks the frequent inspection is needed in order to avoid formations of leakage or breaks. So, the detection of the damage in earlier stages is needed. However, many of the conventional NDT methods are not able to detect early stages of creep damage due to the small dimensions of the voids, which are measured in tens of micrometres. The objective of the work presented was to develop and to investigate NDT technique which enable detection of creep damage in early stages of its development. Investigations carried out have demonstrated that the most promising approach is to use high frequency ultrasonic waves. It was shown by modelling using diffraction model of the focused transducer that detection of small non-uniformities in steel is possible only using focused transducers with frequencies higher than 20MHz. However, even in this case strong amplification (up to 80-90dB) of signals was required using low noise amplifiers. The proposed NDT technique for creep damage detection was based on the scanning of the weld area using high frequency focused transducer. In the second stage the acquired signals were processed using proposed signal analysis algorithm, which is based on relating the properties of the backscattered noise to the characteristics of the metal structure. As the results of processing, the boundaries of the parent metal, heat affected zone and weld metal in ultrasonic image can be indicated. Application of proposed technique for investigation of the samples exposed to different levels of creep damaged revealed that it was possible not only to detect early stage of creep damage but even level of the damage could be estimated. The experimental results were verified using metallographic analysis, which completely validated the proposed ultrasonic approach.

1. Introduction

Creep is time dependent, thermally assisted deformation of component operating under stress. It is often a key factor not only in the design of the components used in the power generation industry, but also in assessment of their remaining life. Pressurised components such as boiler tubing, headers, and stream piping in fossil-fuel power plants operate at temperatures of 530-570°C and 150bar pressure, and this conducive to causing creep damage over the operating life of component. In high strength alloys,
such as P92 grade steel, used in thermal power plants the damage appears in a phenomenon where very small voids form at the grain boundaries of the metal. With time, the voids begin to coalesce first into micro-cracks and then into macro-cracks, leading to fracture. Hence, creep affects a component globally when put under specific conditions but the introduction of a welded joint leads to a particular set of problems, the most serious of which termed Type IV cracking. Type IV position is defined as the fine-grained region on the outside edge of the heat affected zone (HAZ) next to the parent material. The most widely used method of inspecting for the creep at present is surface replication. This technique is sensitive to very small voids (down to 1μm in size) but is limited to the surface of the component. However, the early detection of creep is strategically vital in order that a planned schedule of repair can be undertaken without suffering industrial and domestic electrical power failures in the years to come. The paper presents the proposed ultrasonic non-destructive testing (NDT) technique for creep damage detection which was based on the scanning of the weld area using the high frequency focused ultrasonic transducer and measurement of ultrasonic backscatter, and relating it to the properties to the characteristics of the metal structure.

2. Application of the high frequency ultrasonic for detection of creep damage

In order to evaluate the possibility to use the high frequency ultrasonic focused transducer for creep damage detection the experimental investigations were carried out. The object under investigation was selected to be the special developed P92 steel creep test specimen manufactured from cylindrical blanks and containing the weld joint at the middle. Measurements were performed using the Panametrics-NDT ultrasonic immersion-type V324-SU transducer with central frequency of 25MHz and focal length of 2”, and TecScan Systems Inc. TCIS-3000 6-axis industrial scanner. The scanning of the sample was performed with the angular step of 0.1° and the scanning range was 0-360°. The ultrasonic examination of the test sample was performed at two stages – by measuring the backscattered structural noise in weld, HAZ and parent material on not damaged sample and after its rupture (on the part of sample containing weld). The object under investigation (after rupture) with denoted position of weld is presented in Figure 1. Results obtained using 25MHz focused ultrasonic transducer are presented in Figure 2. As it can be seen, there was observed essential differences between level of backscattered noise in weld, HAZ and parent material. Afterwards, the acquired signals were processed using proposed signal analysis algorithm by relating the properties of the backscattered noise to the characteristics of the metal. As the results, it was observed that the growth of the structural noise with the development of creep and boundaries of the parent material, HAZ and weld metal in ultrasonic image can be indicated.
3. Conclusions

Verification of the developed creep damage techniques using specially created samples demonstrated that it enables to detect defects with dimensions close to the size of micro cracks usually observed in early stages of the creep damage development. It was demonstrated also that the ultrasonic backscattering technique enables to indicate the growth of the structural noise correlated with the development of creep damage and this enables to detect presence of the creep damages in very early stages.