Additional applications with the Alternating Current Field Measurement (ACFM) technique.

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Introduction:

APAVE (Association des propietaires appareils vapeur electrique) The association of owners of electrical and steam raising equipment , are a French government approved organisation who carry out third party inspection and witness hydrotests on pressurised components. The company has eight main offices nation-wide some of which are Technical Centres. One of these is based in Normandy and is involved in 80% of the petrochemical and refinery work in the area. They are involved with metallurgical investigations and in doing so are required to measure the depth of cracks located during these investigations and inspections. In the past this has been carried out using replication and Time Of Flight Diffraction ultrasonic techniques. In 1992 they purchased a model U9 Alternating Current Field Measurement (ACFM) crack microgauge initially to size the depth of cracks. Apave are using it instead of Dye Penetrant (DP) and Magnetic Particle Inspection (MPI) for defect detection sizing and location.
Although normally associated with the detection of fatigue cracks the technique has been used to detect stress concentration cracking (SCC), hydrogen induced cracking (HIC), stress orientated hydrogen induced cracking (SOHIC) in the parent metal adjacent to the heat affected zone and alkaline stress corrosion cracking (ASCC) caused by carbonate cracking. This paper describes case studies reported by APAVE plus some additional applications.

The ACFM technique.

The ACFM technique is a non contacting electromagnetic technique for the detection of surface breaking defects in conducting materials. The ACFM probe induces a uniform electric current into the material to be inspected which then produces a magnetic field which will be disturbed and flow around the edges of a defect if present. Small detectors or sensors are built into probes which are used to detect these magnetic field disturbances. Two components of the magnetic field are measured these are the Bx and Bz, the former for to estimate crack depth and the latter to estimate crack length. These measurements together with software algorithms are used to determine the accurate length and depth of the defect.

Sphere inspection:

These particular spheres have been used for the storage of liquefied natural petroleum and have to be inspected and hydrotested every ten years. It has been known for cracks to occur due to the hydrotest loading operation. The hydrotest can also cause other problems because of the additional weight which will have to be supported by the legs. It has been known for these leg support welds to crack. Magnetic particle crack detection had been carried out in the past to inspect these LPG spheres. If defects were detected then a sizing operation would have to be carried out. In the case of this particular sphere no coating was removed and the welds were inspected using the ACFM technique. Cracks were located in the leg supports and a seam weld. One showed two defects very close together and these were sized individually. When this area was cleaned for rectification the area was re-inspected with MPI and gave only a single indication. If the depth had been determined with the MPI length it could have produced an incorrect evaluation for the fracture mechanics engineer or stress analyst.

Refinery pressure vessel:

This pressure vessel was 4000mm x 1900mm and was located in a refinery. A fire had occurred in the refinery and a pipe bundle had buckled under the heat and had been damaged subsequently damaging the adjacent pressure vessel. The damaged area of the vessel was removed and a patch was welded onto the shell from the inside. No post weld heat treatment was carried out. Because the vessel was operating under a hydrogen sulphide environment and the weld on the patch had not been heat treated it was decided to inspect the internal welds of the vessel after six months. The conditions on the inside of the vessel were dirty and corrosive and instead of using MPI, ACFM was used. The ACFM inspection took three hours whereas past inspections with MPI had taken one day. The scanning rate was six metres in 1.5 minutes. Four cracks were located and sized. These were removed by grinding and ACFM was used to monitor the grinding operation with satisfactory results.

Stress corrosion cracking under insulation:

Staining was noted on the insulation coating on a 6mm wall thickness vertical stainless steel pressure vessel which was operating at 80^{o}C. The vessel was operating in a humid chloride atmosphere and the affected area was just above the insulation support ring. This area was highly stressed because of the original manner of fabrication. The insulation was removed and it could be seen that behind the insulation the area was corroded and damp and it was thought that stress corrosion cracking could have occurred. The surface was unsuitable for dye penetrant inspection so the ACFM technique was applied. By scanning the whole circumference it was possible to determine which areas had been affected by stress corrosion cracking. These produced multiple Bx and Bz indications compared with unaffected areas which produced flat Bx and Bz traces except where a vertical seam weld crossed the area. A similar experience was observed with four large sections taken from a pressure vessel in the USA. This vessel had an internal tray support and stress corrosion cracking was suspected in some of the sections at the tray to shell weld. Even though the surface was very rough the ACFM technique was able to differentiate between the affected and unaffected areas and was able to size the largest cracks. These were found to be 23mm long x 6.9mm deep and 16mm long x 2.3mm deep.

Stainless steel drum used for soap production:

This pressure vessel had a wall thickness of 6mm and a leak had been noticed in one of the weld seams. The cracks were from the inside of the vessel located near to a fillet weld on a support ring. The cracking was identified as stress corrosion cracking. A dye penetrant technique was used on a small area of weld but poor results were obtained due to the cracks being tight and full of contaminants. A trial was carried out on typical samples having the same conditions as the pressure vessel using the ACFM technique. These gave good results which proved the procedure. The ACFM technique was then used on all of the welds on the pressure vessel and cracks were detected and their positions noted. These defects were then sized and the crack growth was monitored.

Double skin carbon steel reactor pressure vessel:

This reactor pressure vessel had been in service for 10 years and the space between the two skins was filled with insulating oil. Cracking was noted along the toes of the longitudinal welds in the jacket section of the vessel. Metallographic replicas were taken from the cracked areas in order to try and identify the type of cracking. The damage was identified as being caused by thermal fatigue. Both fluorescent magnetic particle inspection and ACFM were used together to confirm the presence and the depth of these longitudinal cracks. Good correlation was obtained between the magnetic particle inspection and the ACFM for the lengths of the defects. ACFM was able to provide depth information. The remainder of the base of the jacket was inspected with the ACFM technique. Defects which had been identified, were then removed by grinding and ACFM was used to confirm their removal. The defect depth information produced by ACFM was confirmed in all cases.

Refinery pipeline defects:

In one particular refinery there was a 320mm diameter x 35mm wall thickness pipeline transporting hydrogen sulphide gas which was leaking. Radiography was used to inspect all of the butt welds to identify which welds were defective. All of the welds having defects present were then re examined with ACFM in order to identify if the defects were surface breaking and to measure their length and depth. The largest defect detected was 119.3mm long x 30.4mm deep.

External stress corrosion cracking in a 300 mm diameter pipeline:

A transmission pipeline operating between Marseille and Lyon in France had failed in 1997. This damaged area was repaired but then a second failure occurred in the same section of pipeline. The operators were then requested to inspect the whole pipeline. An internal inspection tool was used to examine the line and five suspect areas were identified. The pipe was coated with 6mm of coal tar coating and the operator thought that the areas were affected by stress corrosion cracking. Past experience had shown that it normally took ½ a day to clean 10 metres of pipe and a further 10 hours to inspect the total area with magnetic particle inspection. The operator decided to use the ACFM technique and each area took 2 hours to inspect and this was through the coal tar coating. The ACFM technique was able to identify and delineate the extent of SCC colonies i.e. their length and breadth. The ACFM technique also gave an indication of depth of the SCC. One colony was measured at 10cm x 3cm and gave a depth of 0.5mm. A second area showed two colonies with depths of 0.3mm and 0.5mm depths. Once these colonies had been identified within the areas of the pipe surface these local areas were cleaned down and the indications confirmed with magnetic particle inspection. There was good correlation between the pipe inspection tool, the ACFM technique and the magnetic particle inspection results. Other areas in the pipeline which had shown no defect areas were inspected as a spot check with the ACFM technique and confirmed that no defect areas were present.

Pressure vessel nozzle defects:

A defect was located adjacent to a shell nozzle using magnetic particle inspection. The operator required to know the depth of the crack. The ACFM technique was used to confirm the magnetic particle indication and to size the crack for length and depth. Both longitudinal and transverse scans of the defect were carried out to confirm its presence due to the difficult location of the crack. The crack was sized as 17.2mm long x 5.7mm deep.

Steam raising boiler:

A steam boiler used corrugated fire tubes to heat the boiler. These tubes which were subject to thermal fatigue were thick and were known to be heavily scaled. The ACFM technique was used to inspect for fatigue cracking and located cracking the largest of which was 60.6mm x 12.9mm deep.

Television transmission mast inspection:

A 800 feet high television transmission mast located in Belgium required inspection. There was only a small number of welds to inspect and the whole mast was covered in an expensive coating which because of access problems would be difficult to remove and replace. ACFM was selected as the inspection technique and a crane was used to place the operator in position. The welds were examined and a defect 29mm long x 2.2mmdeep was located and reported to the transmission company.

Freight container cranes in the harbour of L'Havre:

Open cracks had been seen in the box sections of the large heavy duty cranes used to load and unload the freight containers from the ships. The surfaces of the sections were coated and dirty and the welds to be inspected were located up to 80 metres high. Abseiller inspection technicians were used. Because of the box section geometry an ACFM edge effect probe was used. Initially only detection was required and each crane was fully inspected in 6 hours. Three defects were detected and these were then sized. All of them were in locations where normal probes could be used and the cracks were found to be only shallow between 1-2mm deep.

Timber yard crane:

A heavy duty crane operating in a timber yard in a dirty environment required inspection and the owner did not want to clean the weld areas and remove the coating. The ACFM technique was used to inspect the crane after one visible crack was observed. One further crack was located which was 108.5mm long x 18.4 mm deep.

Cast Iron Cylinder inspection:

The cast iron cylinder was used in a paper mill with pulp on the outside and steam on the inside. A repair had been carried out on the end of the drum and it was feared that further cracking could have occurred. ACFM was used to inspect the ends of the drum and delineate any cracking. Nine cracks were located in the end of the cylinder.

Pulp mill inspection:

Large 50 foot x 12 foot diameter tubular debarking drums with longitudinal stiffeners present are used to debark the logs as a first stage to paper making. The logs are fed into one end and the mill is revolved and the stiffeners are used to remove the bark as they feed through under gravity as the drum rotates. It was found that some of these stiffeners were cracking. More than 100 fatigue cracks were located and sized. The ACFM technique was used to inspect these long stiffeners. Very long defects were located in a number of these stiffeners and these were sized for length and depth. ACPD crack depth profiles were also developed for the longer defects.

Ring gasket in a reactor vessel flange:

A ring gasket which sits in a groove between the vessel and the flange required inspection. The access was difficult and only limited time was available for the inspection. A portable U9 ACFM crack microgauge and a pencil probe was used to inspect the gasket groove. The material was carbon molybdenum steel. The pencil probe was able to inspect the groove and show that there were no defects present.

Machine frame inspection:

A machine frame, located outside, required inspection. The frame was coated but was dirty due to its location. ACFM was used to carry out the inspection using a normal weldscan probe and one defect was located.

Compressor casing inspection:

A cast iron compressor casing was inspected and one defect 58.4 mm x 6.4mm was detected.

A forged ships connecting rod:

A connecting rod from a ships engine was suspected of cracking. An ACFM probe was used in the thread inspection mode and found a crack 23.0mm long x 7.0mm deep.

Boiler tube sheet inspection:

In this case cracking was suspected between the tube sheet and the boiler casing. Access was through two 100mm diameter holes in the header. ACFM was used to inspect the circumferential weld and many multiple defects were noted. The largest defect was sized at 34.6mm long by 1.1mm deep. A dye penetrant technique was used to delineate the defects and a video camera was used to record the location of the defects.

Comments :

The experience obtained by APAVE with the ACFM crack microgauge has shown that the ACFM technique can be used on a vast variety of applications and materials. In the majority of the applications the defects detected were not fatigue cracks. The various forms of cracking located in petrochemical plants and pipelines as well as castings and forgings have been detected efficiently and reliably. Other applications where the ACFM technique has been used such as the inspection of theme park components, highway signs and road and rail bridges have been reported elsewhere.