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Detection of Fatigue Cracks Using Light Emitting Diodes

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Abstract:

Detection of cracks through non destructive methods is vital in present decade and many automotive applications involve repeated stresses and study of fatigue crack is thus essential. The identification of the fatigue crack indicates the condition of fatigue damage evolution at the time of operation, which is normally not within operating environment. The crack luminescence method applied here recognises a clear visibility of the occurring and growing crack in functional part at the time of processing. Various proven experiments show that initiation of crack may be identified at a nucleation stage itself by the assumption that it entered the outer surface due to sensitive coating. There are consecutive layers along with various properties and functions in the coating. Under Ultra Violet radiation, the lower layer emits light like fluorescence. In the event of no harm to the floor, the upper layer protects the fluorescent layer and the reflection of light is being neglected. In the work, for external layer's flaw detection, the light from the Light Emitting Diode (LED) is clearly detectable by visual assessment and also by regular camera systems which also allows possible automatic crack detection. Crack luminescence is expected to improve structural safety, in addition to minimising costs and time for investigations and preventive maintenance.

Keywords **—Fatigue, Crack detection, Coating, Luminescence.**

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I. INTRODUCTION

Material fatigue behaviour is significant in almost every industry field, such as mechanical engineering, product and automation technology or development for aircraft, ships, rail vehicles, cranes, bridges and coastal structures, such as oil refineries or wind turbines [1]. Fatigue cracks can occur in structural applications undergoing cyclic and/or dynamic loading beyond a certain cyclic loading. This initiates a continuous destruction process and the component's residual lifetime is reduced. To trace fatigue damage in an irrational phase, elements through fatigue loading must be routinely tested for safety purposes [2].

Typical detection systems can be unreliable in identifying possible fatigue damage for anti-corrosion coating and operating conditions, depending on the shape and size of the structural materials [3]. For fatigue cracks, there is a routine visual examination of the elements using magnifying glasses if appropriate, is the most common and commonly performed technique. In order to improve the detection through visual inspection, two approaches have typically been introduced to increase the identification of cracks namely dye penetration [4] and magnetic particle method [5]. Although their implementation is characterised by a high time concern and a significant cost of materials, these described technologies grasp an acceptable identification.

A modern, as such crack luminescence system was introduced and patented at the German Federal Institute for Materials Research and Testing [6] to resolve the disadvantages of these existing techniques, providing a highly effective solution for the observation of fatigue crack propagation on engineering structures. The present paper concerns the theory of the system and by means of two exemplary implementations, demonstrates the functionality of the system.

II. EXPERIMENTAL SETUP

With respect to potential high stress, such as joint welding seams, a unique coating system is applied to the surface of different places for crack luminescence. The coating technique involves two elements, a fluorescent layer and a layer which is dark covering the fluorescent layer [7], as shown in Fig. 1(a).

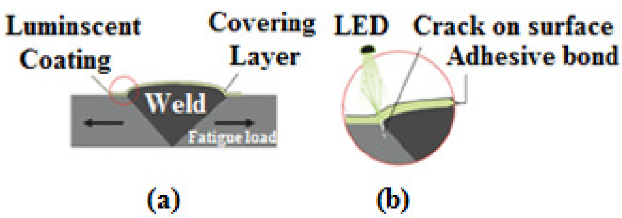

Fig.1. (a) Cracks in Weld seam applied with luminescence coating; (b) LED light reflects the emission from the crack on weld surface

In the case of cracking on the surface of the steel, because of its elastic properties, the two layers rip apart. If energy-intensive rays (UV) penetrate the flaw region, visible radiation is released from the boundaries of the luminescent layer, as shown in Fig. 1(a) and 1(b). It is possible to view clearly the luminescent illumination from a range, which enables web-cams and image recognition tools for automatic remote damage monitoring. This can be lucrative, particularly in places that are not easy to reach, as well as in cases where it is expensive to interrupt the operation of the component for examination of flaws.

MR Chemie has incorporated an aerosol adopted system to replicate thin type of coatings in a quick and functional way and to enable ease inspection. The thickness of the targeted spraying layer is 60-100 mm. 50-70 percent of the total thickness is provided by the fluorescent layer [8].

III. RESULTS AND DISCUSSION

In conjunction with BAM and MR Chemie on special test body coatings that allow sensitivity measurement, various fluorescent and cover coatings have been built and validated. The effect of the thickness of the coatings was thus also calculated and defined. Its long-life fatigue behaviour and its sensitivity during crack formation are two main performance parameters of the luminescence coating.

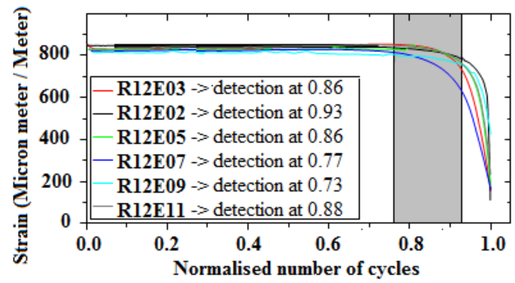

Fig. 2. Strain evolution for the normalized number of cycles with different light emission from LED

The system could on the one view shows the crack as rapidly as feasible while on the other contrary, due to a faulty cover sheet, the coating should not signal properly. Cyclic tensile measurements have investigated these consistency characteristics.

For that the coating were distributed to sheets of thin metal. In one series of tests, the samples were linearly loaded 5 million times to locate any delamination or tearing phase. As a result, no delamination was observed in the coating layers, suggesting the resilience of the coating layers against vibratory loading.

Another series involves cyclic stacking of sheets at the edge of the plate with an earlier defined notch. Figure 2 shows the strain evolution for various stress cycles. After a large number of load cycles originate from the notch, it is expected to form a crack. Finally, this crack will add to the sheet fraction. The moment in time when the crack becomes apparent has received special attention.

At the fillet weld, the crack structure is shown in Fig. 3. After around 120,000 cycles, first ever light flashing was observed clearly noticeable after 140,000 cycles. In the completion of 240,000 cycles, a crack approached a substantial duration and the specimen broke completely at 274,087 cycles.

The Fig. 4 portrays the evolution of strain for the respective crack. The described phases on forming of cracks are numbered on the Fig.3. The curve starts to fall after a shift of around 45 mm/m in the highest strain and the blinking of the occurring crack is clearly noticeable. The value of the maximum strain fell dramatically from about 1,200 to 110 mm/m after 240,000 cycles. The fracturing of the specimen is characterised by 274,087 cycles.

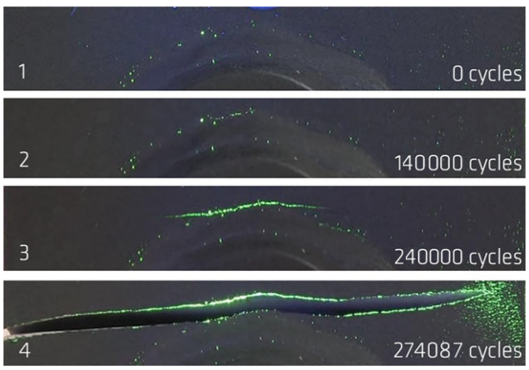

Fig. 3. Formation of fatigue crack during the test

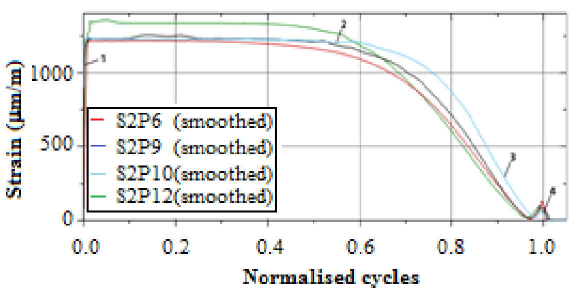

Fig.4. Evaluation of strain at fillet welding

Between the calculation of the strain and the luminescence film, a very precise response was carried out. To track a crack, the sensitivity of the strain measurement also varies with the location of the strain gauges. The closest they are to the crack that happens, the quicker shifts in strain are seen.

Also noticeable in some fillet weld samples was the form of a second crack on the rear face of the weld, which shuttered then after the crack since there was no loading any more. By use of this type of coating, the opening and closing of a crack may be established. The crack underneath was not visible after removing the coating, but penetrating dye inspection and microscopic inspection later confirms the presence of such a repeating crack.

IV. CONCLUSIONS

The analyses mentioned show that the crack found by LED light with luminescence coating method has high sensitivity. Early identification of the crack that was well correlated with the strain observations or even significantly dramatic shifts in the experimental value was reported in all studies. This shows that for examinations of crack growth activity, the technique is sufficient. The research methods also show the reliance of the correct position on measured strain based crack detection.

Uneven surfaces can increase examination costs using traditional crack detection methods even the surface texture of the crack reflected light does not make a difference. Without knowing the actual position of the crack in advance, the crack luminescence makes application on any large and rough surface. This makes the approach suitable for continuous monitoring with the use of camera techniques that are particularly useful in hard-to-reach locations.

The technique is also useful and especially useful for monitoring dark areas where cracks are difficult to see in general. For an operation on undamaged structures or materials, crack luminescence is not just beneficial. Any further creation of existing cracks or new crack formations can be found by applying the coating to potentially damaged parts. For structure-operating businesses that are threatened by crack luminescence, operations and maintenance would have a huge impact.

Most applications of crack luminescence solutions have been explicitly ruled out in laboratories on steel structures where tolerance to environmental factors is not compromising.

Therefore, future research and development will focus on the sensitivity of the coating to weather phenomena such as tornado, rain, precipitation or wind and their influence on tracking consistency.

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