LUMINESCENCE-BASED EARLY DETECTION OF FATIGUE CRACKS

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1. Introduction

At vibrational stressed mechanical components fatigue cracks may be initiated after a certain number of load cycles. This process leads a steady destruction and the residual lifetime of the structure is limited. For safety reasons components under fatigue loading need to be inspected frequently to detect fatigue damage in an uncritical stage.

In dependence of the type and size of the structure and its relevant components, of its anti-corrosion coating and of operational circumstances conventional inspections methods can be unreliable in detecting fatigue cracks. Conventional NDT methods for crack detection such as ultrasonics are not suitable for continuous monitoring of structural parts for they are locally applied. Therefore, the application of these methods requires the information of the crack location in advance which especially for large structures is challenging.

A new method, the so-called crack luminescence, provides an efficient solution for continuous or higher frequent monitoring of structures under fatigue loading. In a cooperative research project between BAM and MR Chemie GmbH different fluorescing and cover coatings were developed and tested on special test devices which allowed the determination of the sensitivity, robustness against mechanical wear and, last not least the applicability of the system.

The present contribution describes the principle of the method and shows its functionality by the means of an exemplary application.

2. Principle and functionality

For crack luminescence, a special coating system is applied on the surface of critical locations regarding possible high stressing, for example weld seams. This coating system consists out of two components, a fluorescing layer and a dark layer which covers the fluorescing one (see Fig. 1) [1].

In case of crack occurrence at the steel's surface the two layers rip open due to its adhesive properties. If then energy-intensive rays (UV) enter the crack, the boundaries of the luminescing layer will emit visible radiation, as schematically illustrated in Fig.2. This luminescence light can easily be seen from distance which allows for an automatized remote damage monitoring using webcams and image recognition software. This can be profitable, especially at locations that are not easy to access as well as in cases, were an interruption of the structure's operation for inspection issues is costly.

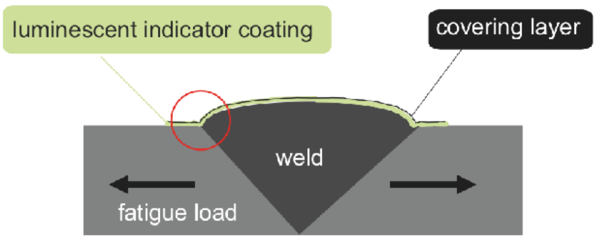

Fig. 1. Application of the crack luminescence coating at a welding seam [1].

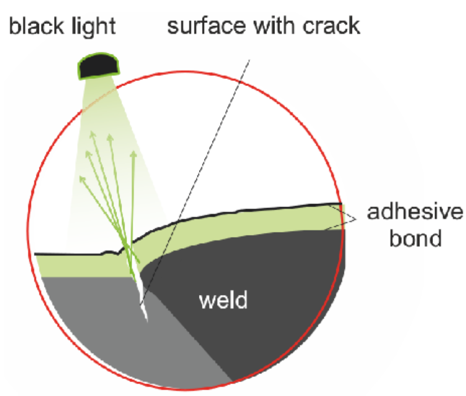

Fig. 2. Case of a crack and the emission of visible radiation [1].

To reproduce thin coatings in a fast and applicable way as well as to ensure a user-friendly handling MR Chemie developed an aerosol can based system. The targeted sprayed layer thickness is 60 to 100 µm. The fluorescing layer makes 50 to 70 % of the total thickness [2].

3. Exemplary application

The crack luminescence method was exemplary tested on butt weld seams [2]. There, fatigue damage was induced by cyclic tensile loading. The tests were monitored by strain gauge measurement and video capture. Fig. 3 shows a butt weld before and after the application of the fluorescing layer.

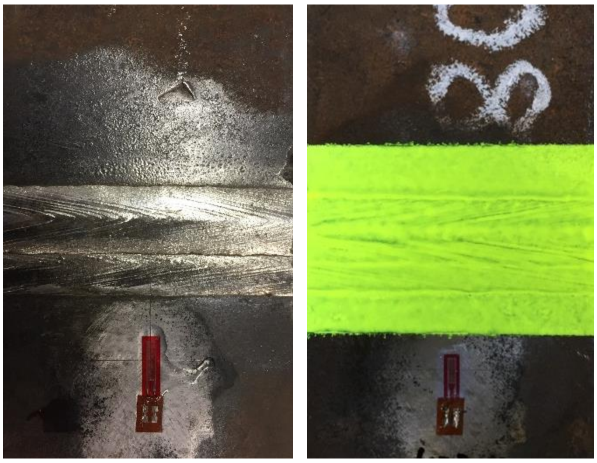

Fig. 3. Butt weld without and with fluorescing coating.

4. Results

Fig. 4. shows the result in form of three pictures of three different stages of the crack formation.

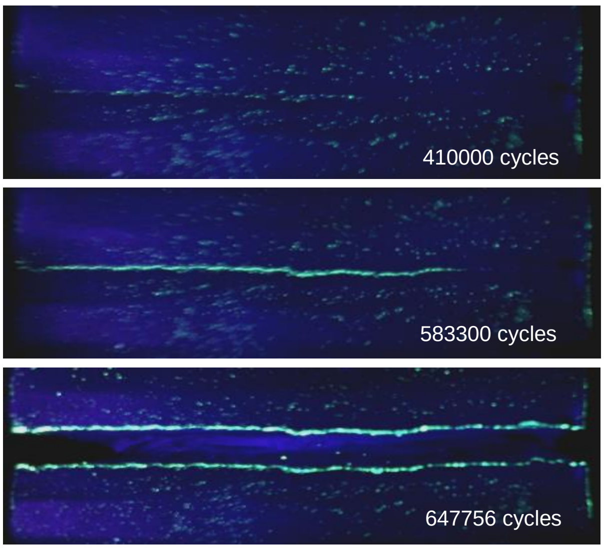

Fig. 4. Evolution of crack formation.

In Fig. 5 the evolution of strain is shown, marking the three specific times, when the pictures were taken. The first mark "a" refers to the point of time (410 000 cycles) when the luminescence-based blinking of the crack started (see Fig. 4). At the same time the maximum strain started to decrease (see Fig. 5). Afterwards, the brightness of the crack's blinking consistently increases. The mark "b" refers to the point of time (583 300 cycles) when the maximum strain has decreased by 5 % (see Fig. 4 and 5). After 647 756 cycles the specimen fractured.

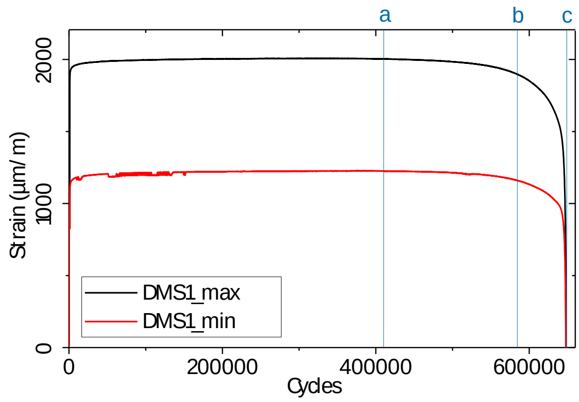

Fig. 5. Evolution of measured strain .

5. Conclusions

The presented study shows a high sensitivity of the crack luminescence and a very good comparability with the strain measurements. It was proved that also without knowledge of the exact location of the crack the method can reliable detect fatigue crack at a butt weld seam. The crack luminescence is a promising approach to support inspections of fatigue-prone structural parts.

Acknowledgements

This work was funded by the German Federal Ministry for Economic Affairs and Energy within the ZIM program; support code ZF2201092ZG4.

References

[1] Mehdianpour, M., Risslumineszenz – A new method for detection and monitoring of fatigue cracks, VSVI-seminar bridge- and structural engineering, Braunschweig, in German, 2015.

[2] Makris, R., Hille, F., Thiele, M., Kirschberger, D., Sowietzki, D., Crack luminescence as an innovative method for detection of fatigue damage, *J. Sens. Sens. Syst.*, 2018, 7, 259–266.