

Non-destructive testing of stay cables: Field application in South East Asia

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Abstract:

In the Fall of the Year 2000 a Thai-Swiss partnership was awarded the contract for the non-destructive assessment of the conditions of the 68 stay cables of a 14 years old bridge in Bangkok using a magnetic flux leakage method. The bridge was subject to high levels of fatigue stress due to the intense traffic and to the weight of the commercial vehicles transiting on it. The main constraint to the execution of the inspection was that at no time the bridge could be closed to traffic due to its strategic role in the flow of the City traffic. The expertise of the Thai-Swiss project-oriented partnership met the needs of the customer. A report about the conditions of the stay cables was delivered to the customer in November 2001.

Body:

In the year 1987 the RAMA IX cable stayed bridge, connecting Bangkok to Thonburi on the two sides of the Chao Phraya River was opened to traffic. The bridge was at the time of its opening the largest of its kind. After 14 years of operations, a detailed inspection of the stay cables was considered necessary. For this purpose, the customer selected the non-destructive evaluation (NDE) method proposed by EMPA.

For several decades, until the year 2000, EMPA has been developing and applying non-destructive methods for the in-situ assessment of the conditions of the steel cables of aerial tramways. Before EMPA handed this activity over to the private industry, it was decided to apply the long time experience and know how to the assessment of large steel cables. The transfer of the technology applied to the relatively small diameter tramway cables (generally not exceeding $\varnothing 70$ mm) to large diameter cables is a non-trivial task.

The main challenge in the assessment of the condition of stay cables of large dimensions such as the cables of RAMA IX Bridge with magnetic methods is the need to magnetically saturate the large cross section (up to 22400mm^2) of the cables. In order to obtain the high field intensities needed to saturate the cables the new equipment used for the NDE of large diameter cables is fitted with an electromagnetic device instead of the permanent magnets used for small diameters. In connection with this modification a number of new hardware and software developments were needed in order to obtain a reliable prototype of the equipment for the use on the field.

As a result of the development work performed in the years 2000 and 2001, EMPA could deliver its decennial know-how in the field of non-destructive evaluation of steel cables in connection with a newly developed computer based NDE equipment.

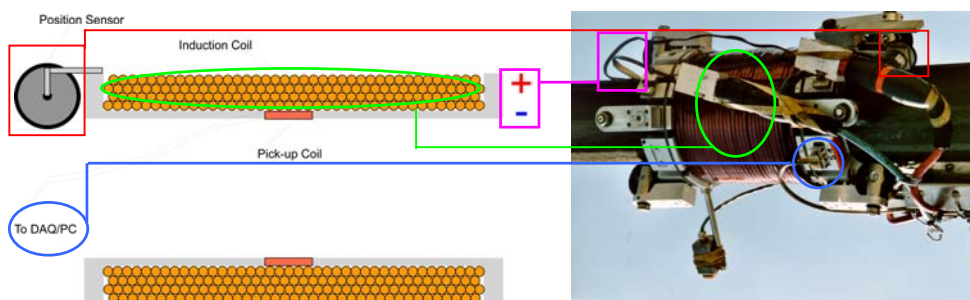


Figure 1: Schematic representation and of the NDE equipment with its most important components

The equipment represented in figure 2 has two functions:

1. A magnetic field H is generated by a strong current circulating in the induction coil (highlighted in green). The field is approximately parallel to the axis of the cable under investigation.
2. In proximity of discontinuities in the cable (wire fractures filled with air or with an oxide exhibiting magnetic properties different from steel), the induction field B is perturbed (so-called magnetic leakage field, MLF). This deformation of the induction field B induces a tension in the pick up coils built into the equipment. The signal measured by the pick up coils is recorded by a PC-based data acquisition system (connection highlighted in blue) as a function of the position of the equipment. The position sensor is highlighted in red in figure 1. A number of sensors (pick up coils) are positioned around the circumference of the cable. The signals from such sensors are recorded separately and can be used to generate a map representing the intensity of the MLF on the surface of the cable (gray scale map in bottom section of figure 2). From the recorded map it is possible to deduce, where along the axis of the cable wire fractures are located. Based on the shape of the recorded signal it is also possible to obtain information about the position of the defect within a given cross-section and about its size, as stated by equations (1) and (2).

An example of the signal recorded during the inspection is given in figure 2. The presence of a signal with the typical 'Mexican hat' shape indicates the presence of a defect in the cable.

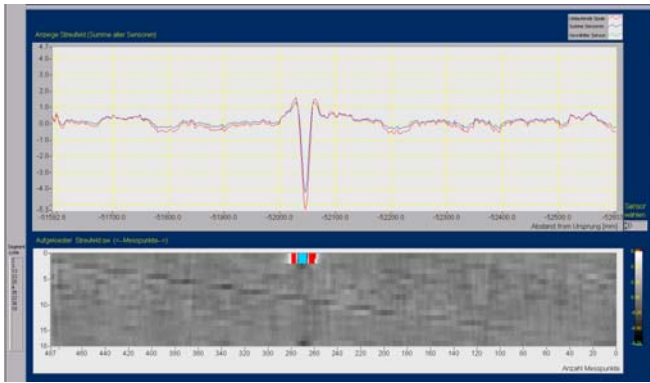


Figure 2: Portion of one scan indicating the presence of a defect in a stay cable. The recorded signal is proportional to the 1st derivative of the vertical component of the magnetic leakage field

A quantitative evaluation of the signal in terms of peak intensity and peak width gives an indication of the size and position of the defects shown in figures 3 and 4.

The magnetic flux leakage (component vertical to the surface of the object) of a subsurface cylindrical hole (permeability μ_i) with radius a , drilled in a material of permeability μ_m at a depth of h can be approximated as:

$$H_y = \frac{m_{eff}}{(x^2 + y^2)^2} 2xy - 2H_a a^2 \frac{2xy}{(x^2 + y^2)^2} \quad (1)$$

Where H_a is the applied field strength. m_{eff} is:

$$m_{eff} = \frac{2\mu_m}{\mu_m + \mu_i} \left[1 - \left(\frac{\mu_m - \mu_i}{\mu_m + \mu_i} \right)^2 \left(\frac{a}{2h} \right) \right]^{-1} \frac{\mu_m - \mu_i}{\mu_m + \mu_i} H_a a^2 \quad (2)$$

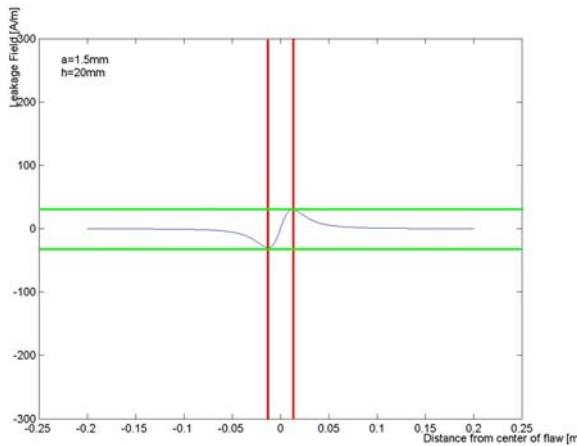


Figure 3: Normal component of the leakage field for a flaw with a radius of 1.5mm located 20mm under the surface. The field has been calculated 2mm from the surface of a material with an assumed permeability μ_m of 1000. The external field is 5000A/m.

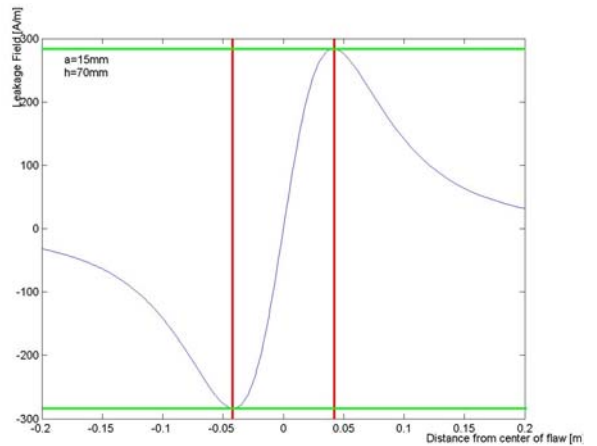


Figure 4: Normal component of the leakage field for a flaw with a radius of 15mm located 70mm under the surface. The field has been calculated 2mm from the surface of a material with an assumed permeability μ_m of 1000. The external field is 5000A/m.

Experimental results confirming the equations of (1) and (2) were recorded at EMPA⁺. Simple numerical simulations of MFL generated by such defects have been performed. In the near future more accurate simulations are expected to allow for a quantitative interpretation of the recorded signals, leading to a better understanding of the condition of the examined cables.

The operations on the bridge were completed on September 1st 2001, in agreement with the proposed time schedule. The final report delivered in November 2001 contained information about the overall number of defects found in the inspected cables as well as a qualitative indication of the position and magnitude of the defects.

More work is currently being done to develop methods based on finite element calculations to give a quantitative interpretation of the recorded signals

References

⁺ Bergamini, A.: "Nondestructive testing of stay cables", Proceedings IABSE Conference on suspended bridges, Seoul, Korea, 2001