ACOUSTIC EMISSION ASSESSMENT OF NON VISIBLE DEFECTS ON MULTISTRAND CABLE

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One type of deterioration in bridges is the consequence of steel cable damage. This degradation occurs by cracking and then rupture of elementary steel wires, constitutive of the cable. We have tested acoustic emission as a technique for the detection and the monitoring of the non visible disorders taking place in these cable. These defects are already broken wires under an anchorage. The installation of an acoustic monitoring system permits us to have a good detection of this defects in spite of the damping on this type of structure. Global AE parameters like number of events, counts and amplitudes can be used for an easy distinction between a healthy cable and a damaged one. Indeed, an increase of acoustic activity by a factor 25 to 100 is noticed when defects are present in a cable. The final objective of this research is to provide to transportation management authorities an easy to use bridge inspection method to quantify the healthiness of the steel cables.

Introduction

The cables are fundamental structural parts of the long length bridge, such prestressed concrete bridges, suspension bridges and stayed cable bridges. Their durability and their safety structural depend not only on the good behaviour of the cables, but also of our capacity to detect in time the defects which affect them (1). However, the detection of these damages - wire failures, development of corrosion - is made often difficult by their own protection (duct, grout,…) or by their configuration in the structure (cables embedded in the concrete, parts of cables under collar or anchorage device).
The currently available techniques allow the assessment of the cables in their accessible parts (visual monitoring, electromagnetic, ultrasonic techniques) or their monitoring (2,3). But it doesn’t exist a fully satisfactory method to examine the cables in their non accessible parts. Among the possible ways, Acoustic Emission (AE) seems to have very good capacities (4-6). For the cables of civil engineering, the most important purpose is to locate the existing defects, such broken wires due to corrosion or fretting fatigue (7). Study reported here concerns the broken wires detection by Acoustic Emission in the hidden parts of multistrands cables, to develop a method of damage inspection of the stay cable or suspension bridges using this technology.

Cables and techniques

The cable used to test our AE technique consists a multistrand rope of seven layers for a total diameter of 56 mm. Two external layers are made up of wire with Z profile. During these tests, a specific set-up devoted to cables application is used. The cable is put in tension at 200 kN and in vibration by applying a transverse force with a pulsating system powered by an electric motor (Figure 1). This last was optimised by add-in a variable speed unit making it possible the cable to vibrate in the vertical direction with displacements from 5 to 15 mm and for frequencies ranging between 10 and 30 Hz for our application.

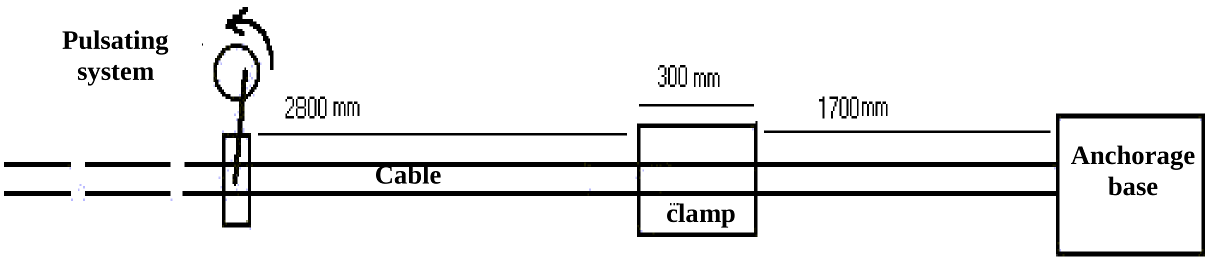

Figure 1 : Rope test set-up with a cable put in place.

Concerning this study with broken wire inside of the base anchoring, this is carried out by producing artificial failures on the cable before its installation in the anchorage base. Three wire ruptures zones are made on the same section of the cable at 35 mm of the exit of socket with three levels of damage spaced of 120° around a diameter (zone 1 **:** 7 wires ; zone 2 : 2 wires ; zone 3 : 5 wires, wires located on the external layer). Another reference rope without defects is carried out under the same conditions. Concerning broken wire inside a hanger clamp, two adjacent wires of the external layer were cut on the cable under the clamp. The choice of these types of configuration comes from the knowledge on the damages really met on bridges in order to better represent the damage modes of the cables in service.

The Acoustic Emission system (AE) is composed of 4 acquisition channels and has its own data processing and visualisation tools. The waves coming from the cable are collected with the help of resonant piezoelectric sensors (300 kHz) stuck on the rope. These signals pre are amplified (40 dB), filtered between 20 and 1200 kHz before arriving at the AE system itself where a numerical filtering between 10 and 600 kHz is done. According to AE studies concern the anchorage base or the hampers clamp, location of the sensors is different (8). Two configurations were carried out for the anchorage base :
4 sensors at 5, 10, 15 and 20 cm from the anchorage base on extension of a damaged zone
3 sensors at 10 cm on each extension of the damaged zones created
Three configurations done for the clamp :
Sensor 1 at 5 cm from the clamp, sensor 2 à 5 cm from the clamp on extension of a damaged zone, sensor 3 at the opposite side of sensor 1
Same locations for sensors 1 and 2, sensor 3 on the clamp
Same locations for sensors 1 and 2, sensor 3 at 180° from 1 on same section

Acoustic emission results

Characterisation of the background noise

The first stage consists in characterising the background noise from the healthy and faulty cables (9). The detection threshold is fixed at 35 dB. An AE test has allowed us to know that we don’t have acoustic activity when the rope is not under cyclic testing. When rope is put in vibration with increasing amplitudes, we observe an acoustic activity not coming from pulsating system but from the waves propagation in the cable since the base or the clamp. For the broken wires under the base, the number of hits detected by sensor during acquisition increases from 100 for a cable without defects to 2500 for a damaged cable. Moreover, AE on healthy cable decrease after several tests, which corresponds rather well to a resin degradation mechanism (Figure 2). This progressive cracking has AE characteristics quite different from the signals coming from the defects. This phenomenon was already identified by other authors on multi-layer cables (8,10). By deduction, the strong acoustic activity recorded on the damaged cable thus comes mainly from the broken wires. For the defects under clamp, the vibrating rope creates rubbing between the clamp core and the wires of the external layer what involves an not negligible AE activity (10 hits for a cable without defects, 100 for a damaged cable) but which has frequency characteristics quite different.

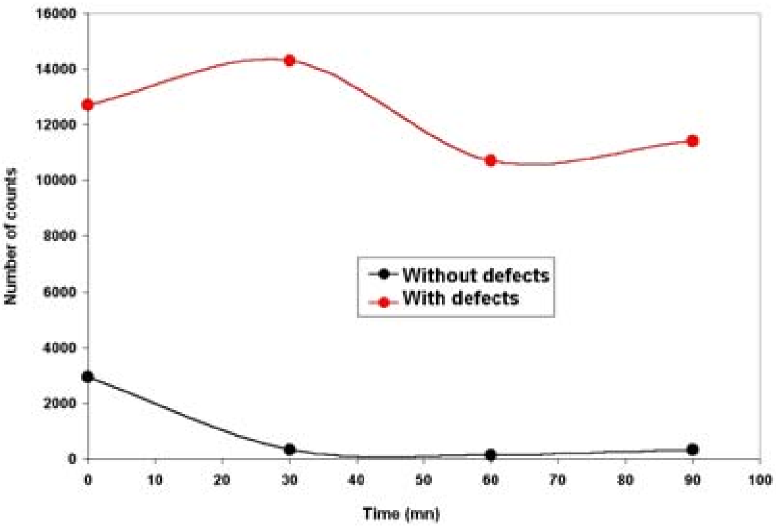

Figure 2 : Evolution of the number of AE counts versus time in the presence of defects or not on cable.

Comparison between healthy and damaged cables

Global AE activity

The presence of broken wire produces a friction between them and the undamaged wires This relative displacement (fretting fatigue) between these wires is a phenomenon which does not present a Kaiser effect (11,12). The evolution of the conditions of contact of this friction influences acoustic emission (13,14) which is stabilised after several cycles. The cable is thus put in vibration during several minutes before acquiring the AE signals.

A first comparison of acoustic activity between cables produces promising results. The AE parameters selected for this analysis are the number of hits, the number of counts and energy. They are large-scale parameters but for an in situ application of this technique, the data processing must be simple. A simple filtering allows us to optimise the results obtained by applying a filter to the number of counts (> 3). Then, the comparison between tests on healthy and damaged cables is done The distinction is relatively easy between the two cables by comparing the parameters of EA, this being checked for the three parameters (Figures 3 and 4).

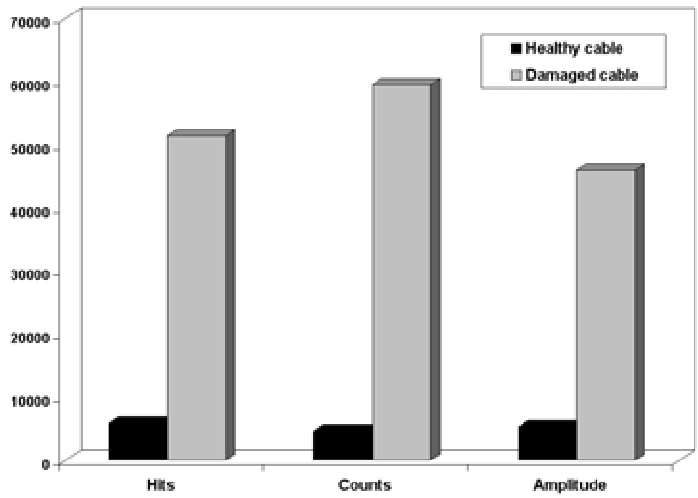

Figure 3 : Acoustic emission activity according to the presence or not of defects on the cable under base.

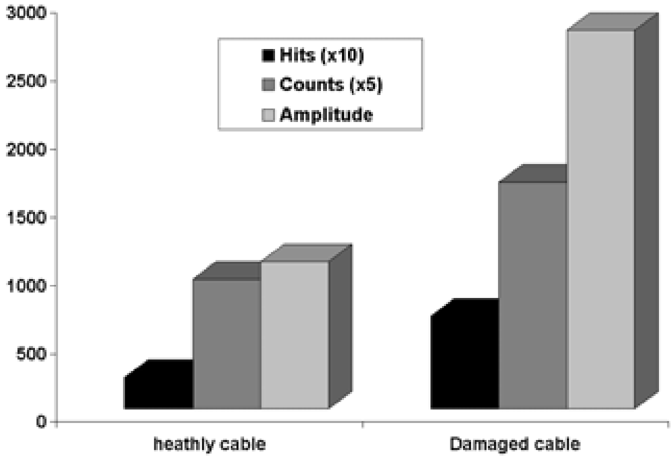

Figure 4 : Acoustic emission activity according to the presence or not of defects on the cable under collar.

Frequency analysis

It is important to be able to well separate the other causes of AE (resin cracking, friction of external wire on clamp core) of that which interests us (friction between wires). For that the criterion of a more important acoustic activity in the presence of broken wires is not sufficient to be able to qualify a time evolution of the damages (18). One then uses the hits distribution according to their frequencies (here, FFT width at 30%). The frequency distribution is very dispersed on a cable with defects under the base compared to a cable without defects. The latter presents a frequency distribution centred around 350 kHz which is close to the frequency resonance of the sensor and attached to the cracking of resin (8,10) (Figure 10). In the case of defects under collar, the frequency distribution is different with a clear prevalence from the low frequencies for the healthy cable compared to the cable with defects (Figure 13). The two types of friction would be identifiable by their frequency signatures. In order to characterise the time evolution of the damage the application of special filters and the acquisition of usual AE parameters should be enough to evaluate the evolution of the cable compared to a preceding inspection.

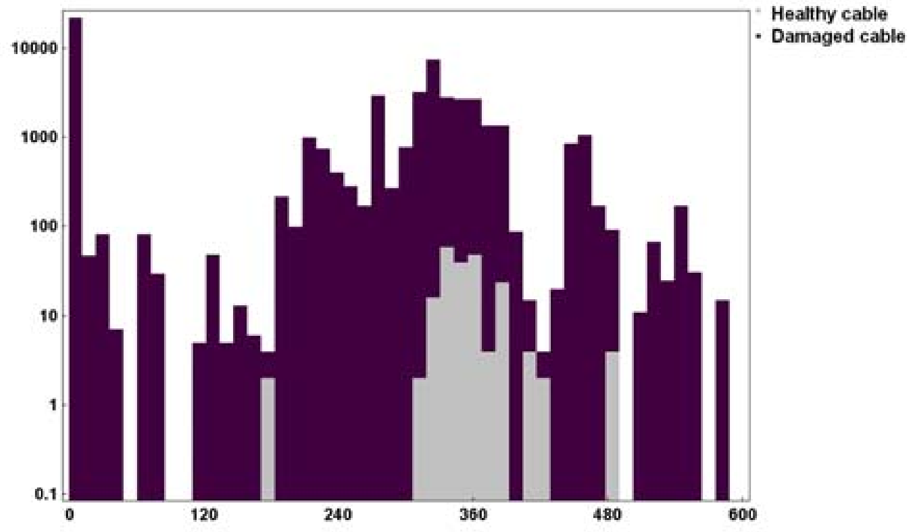

Figure 5 : Frequency distribution of AE counts in the presence of defects or not under base anchoring.

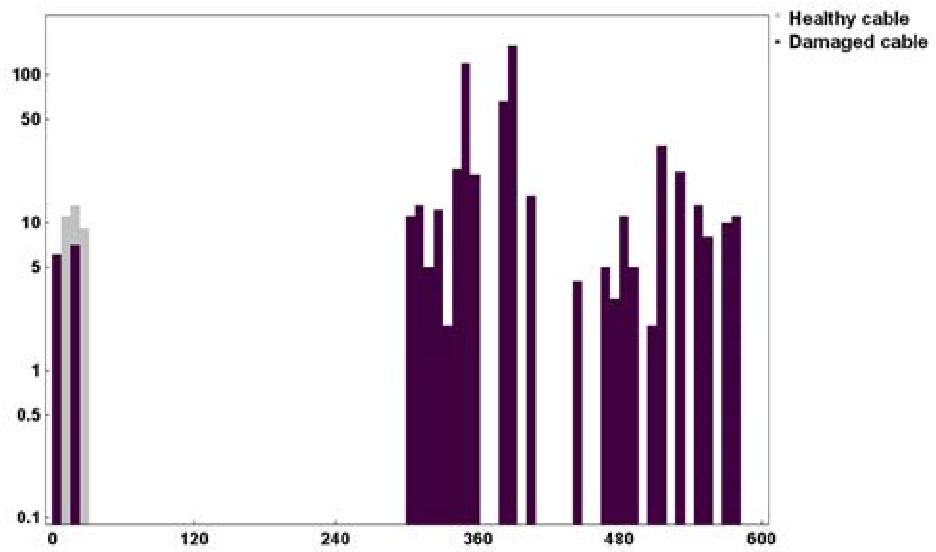

Figure 6 : Frequency distribution of AE counts in the presence of defects or not under clamp.

Estimation of the degree of damage

Moreover, this inter-wire friction strongly depends on the gravity of the damage. Thus, the acoustic activity is proportional to the number of broken wires on the damaged cable which modify the conditions of contact (14) (Figure 7). The parameter of the most relevant is the number of counts acquired during the test. It should make it possible to give a first semi-quantitative diagnosis of the state of degradation of a cable.

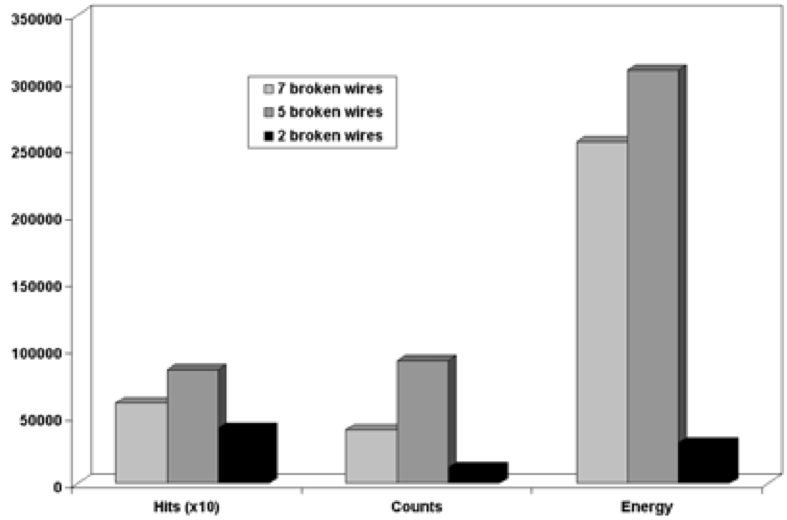

Figure 7 : AE activity for three degree of degradation under base anchoring of a multilayer cable

Conclusion

In order to meet a need for the managers of bridges structures to know the degree of degradation of the non-visible or accessible wire ropes, we have evaluated the technique of Acoustic emission (AE). Two types of configuration frequently met on structures were chosen, a cable under an anchoring base and a cable under a clamp. The defects created are broken wires. The source of AE is friction between broken wire and those remained intact. Detection by AE of this friction between wires is possible for the two configurations with a more important AE activity in the presence of defects on the cable, which allows the distinction between a healthy and damaged cable. Using simple filters, the populations of acoustic events corresponding to the other AE sources and friction can be isolated. The degree of gravity of the damage (2, 5 or 7 broken wires) can be also discriminated by AE. All that should enable us to measure a time evolution of the damage (stability, deterioration) on bridges.

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