# DURABILITY OF ORGANIC COATINGS UNDER MECHANICAL STRESS

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## Introduction

The mechanical properties of coatings are of major importance in maintaining the protective as well as the decorative functions during their service life. Paint films are subjected to many types of mechanical forces and deformations /1-3/. Among other impacts they may experience a succession of deformation cycles. That type of stress has often a fatigue character. There is a big number of coating-protected constructions operating under cyclic stress i.e. bridges, ship hulls, cargo cranes, masts, car bodies and many more /4,5/. Field inspections of organic coatings performed on these objects often reveal premature coating degradation. Durability of the protective films on stressed constructions is significantly lower than of the same systems, however deposited on non-stressed objects. The problem becomes even more urgent with time as the mechanical properties of coatings change during their exploitation, thus determining how long a coating film can preserve its physical integrity and can fulfil its protective role satisfactorily.

The purpose of this paper is to assess the impact of aging on coating resistance to cyclic mechanical stress on the example of a coating designated for bridge structure protection. Fatigue effect on as-received coatings has been compared with the one on the same system, however pre-exposed in damage enhancing conditions (UV radiation).

## Experimental

The systems under investigation was vinyl coating on St3S steel substrate – thickness $60.8 \pm 7.4$ μm. The substrate was in the form of an isosceles triangle to provide uniform stress distribution all over the specimen's surface /6/.

One set of samples was tested against cyclic mechanical stress in as-received form. The second one was exposed to the conditions enhancing coating degradation, namely 3 months exposure to UV radiation.

All the specimens were subjected to bend/ release cycles of the frequencies $f_1$=0.7Hz, $f_2$=0.35Hz, $f_3$=0.07Hz respectively, simulating fatigue damage. The force applied was adjusted experimentally and provided maintenance of the substrate within elastic deformation region.

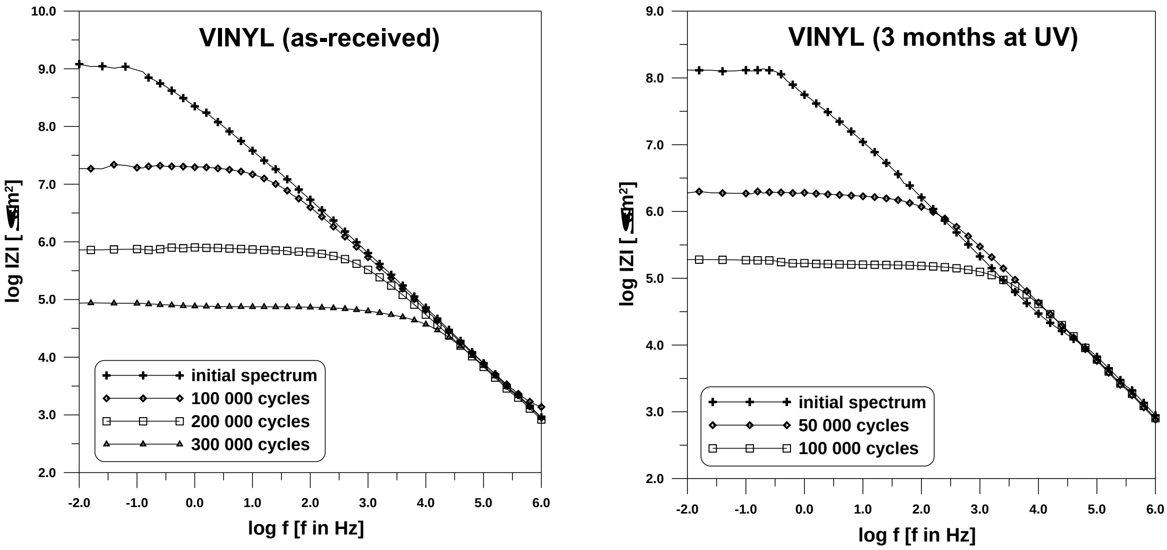
The state of the coatings was evaluated using an electrochemical impedance spectroscopy technique. Impedance spectra were registered regularly after fixed number of bend/ release cycles. The investigation was carried out in a two-electrode system, in the frequency range 1 MHz – 1 mHz, upon immersion in 3% NaCl.

## Results and discussion

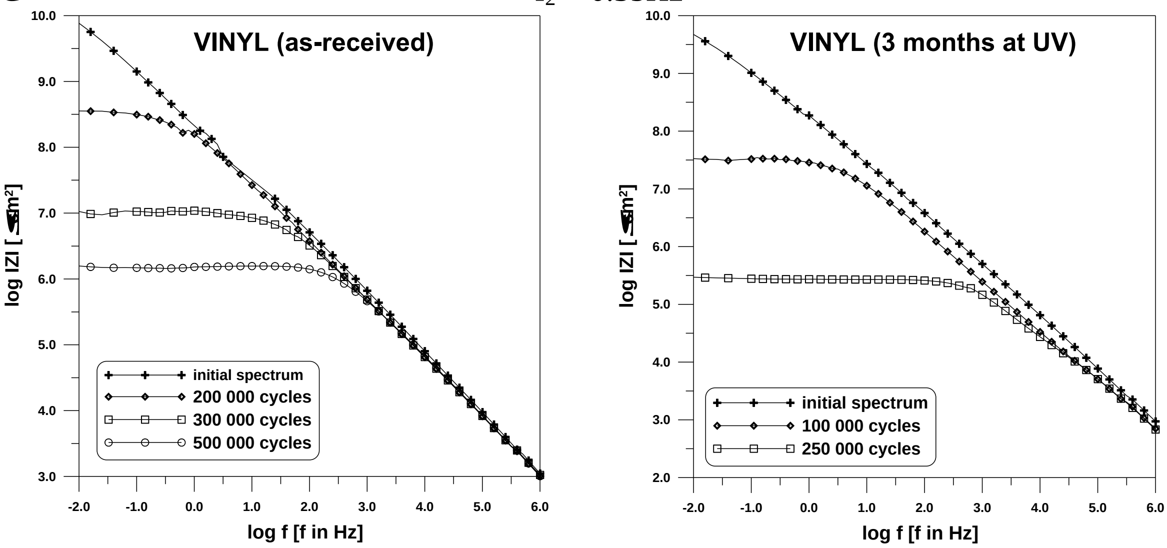
The experiment revealed that none of the samples had been totally immune to imposed test conditions. Fig. 1 presents the impedance spectra registered for examined specimens. Both as-received and UV pre-exposed samples exhibit gradual deterioration of protective properties throughout the test, exemplified by a progressive drop in the impedance. In almost all cases investigated the impedance decreased by a few orders of magnitude falling below the level of $10^6$ $\Omega cm^2$, which is regarded to be a value distinguishing barrier coatings from defected ones that must be discarded from further service. Proceeding with more detailed analysis it can be noticed that pre-exposure to harsh conditions enhanced fatigue damage of the protective films. Accordingly UV irradiation made vinyl coating significantly more susceptible to fatigue degradation, especially at highest frequencies of mechanical cycling ($f_1$=0.7Hz and $f_2$=0.35Hz) – comp. Figs 1AC and Figs 1BD respectively. It can be spotted that all pre-exposed samples performed worse at any stage of the test as compared to their non-UV irradiated counterparts. The changes within the polymer structure induced by UV made the material more rigid thus less readily responding to cyclic deformation.

The results obtained yield also interesting conclusions from the dynamo-mechanical point of view as far as rheological behaviour of the coating is concerned. The experiment revealed a certain regularity – the higher is the frequency of mechanical deformation, the faster pace of degradation is. Such rule holds true for both vinyl specimens: as-received as well as UV-exposed ones. In this way the results support the statement that the time-to-failure should be inversely proportional to the frequency of stress fatigue cycles. It also seems to be justified to attribute such behaviour to the time necessary for the polymer to dissipate the energy of impact before the succeeding fatigue cycle. While experienced with high-frequency cyclic deformation a coating material is not able to release all the stress promptly enough, especially when such ability is impaired by some other degrading factors for instance UV radiation. That situation leads to accelerated stress build-up within polymer material resulting in fatigue failure.

**A** $f_1$ = 0.7Hz **B**




**C** $f_2 = 0.35$Hz **D**




**E** $f_3 = 0.07$Hz **F**

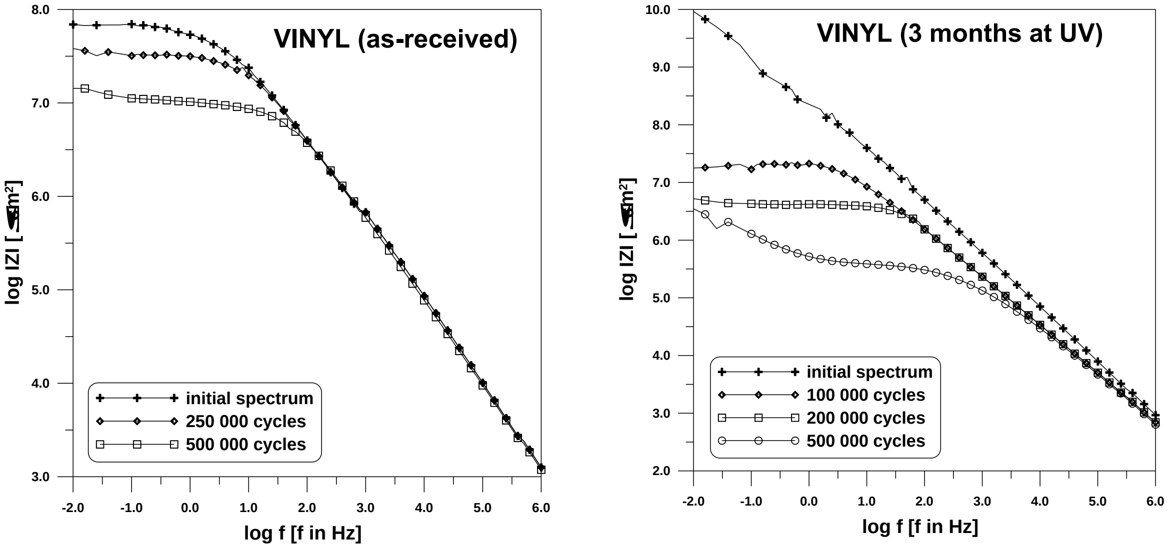



Fig. 1. Impedance spectra in Bode format for vinyl coating in as-received and UV-preexposed state, for three frequencies of mechanical cycles.

## Conclusions

The results presented seem to highlight the problem of significant practical importance, however not widely investigated so far. In real exploitation conditions UV radiation originating from the sun activity is often combined with the fatigue impact of cyclic mechanical stress. The experiment proved the synergistic effect of these factors on lifetime limitation of organic coatings. It was shown that the dynamics of coatings degradation was directly related to the frequency of cyclic stress imposed.

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