The Fatigue Deterioration Potential of Railway Traffic

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Summary

In this paper, a method for predicting the evolution of fatigue deterioration of structural components using continuum mechanics numerical simulation is presented. At a first stage, prediction will be limited to the evaluation of the end of the initiation phase of the fatigue process. The method is intended for cases where the loading history demonstrates certain repetitiveness (as it is the case for railway traffic induced loading) and is based on the characterization of the deterioration potential of these loading histories by means of the physical quantity of generated entropy per generalized loading cycle. The basic steps towards the development of this method are also presented. At the end, an example of application on a simple reinforced concrete railway underpass is outlined and the expected benefits of the application of this method are explained.

Keywords: fatigue, entropy, continuum mechanics simulation, generalized cycle, railway bridges.

1. Introduction

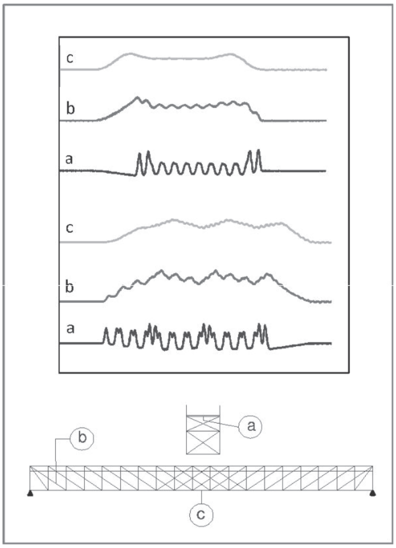

Fig. 1: Strain-histories recorded on three different elements of a steel truss bridge.

In current engineering practice, the evaluation of the remaining fatigue life of bridge components under traffic induced loading is often based on the use of S-N curves in combination with cycle counting methods and Miner's damage accumulation rule. An important advantage of this approach is the use of macroscopically observable material properties and of stress and strain variables that can be obtained from structural, sectional and stress analysis. On the other hand, the reliability of these purely empirical methods heavily relies on the presumed equivalence of the actual loading conditions (including stress triaxiality and stress history characteristics) to the simplified loading patterns applied during the tests from which the "corresponding" S-N curve has been derived. Hence, an improvement in the fatigue evolution prediction methods can be achieved through proper understanding and consideration of the actual deterioration processes involved in the fatigue mechanism. However, most of these processes

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evolve in geometric scales (microscales) which are incompatible with the fundamental homogeneity assumptions of continuum mechanics. Thermodynamic approaches aim at bridging the gap between microscopic and macroscopic description of the response of matter to external stimuli.

In this work an entropy approach is attempted following the work of Naderi, Amiri and Khonsari [1]. Entropy approaches are based on the postulate that every deterioration process is in fact a dissipative process of microstructural rearrangement that results to entropy generation [2]. Hence, generated entropy constitutes a fundamental deterioration measure that could be used to characterize the deterioration potential of loading histories on specific components. Calculation of generated entropy is based on the proper identification of all the important dissipative processes that are activated during a loading history and a proper description of them through appropriate constitutive laws.

On the other hand, characterization of an entire loading history, which is essentially random, by any deterioration measure, implies that some kind of statistical homogeneity can be defined over its duration. This is the case of loading sequences which demonstrate certain repetitiveness, as it happens with the railway traffic induced loading. In these cases a statistical homogeneity can be defined by means of the notion of the generalized cycle. As it can be seen in Fig. 1 each train crossing gives a distinct signature on each component of a bridge. A sequence of crossings of different train types which is repeated regularly in time corresponds to a generalized cycle of the resulting loading history.

Hence, it seems interesting to investigate whether the quantity of entropy generation per generalized cycle can be used as a useful parameter for the characterization of the fatigue potential of loading histories.

2. Application

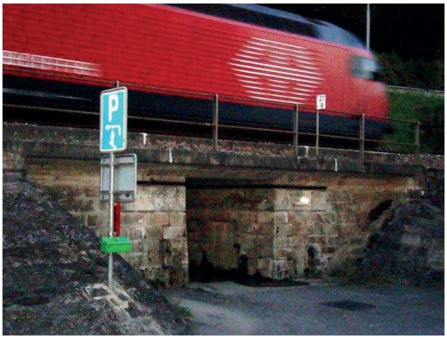

Fig. 2: A small railway underpass.

The proposed method will be applied for the investigation of the evolution of deterioration of an existing railway underpass depicted in Fig. 2. The structure consists of a reinforced concrete slab simply supported on masonry abutments. In this simple structure, fatigue deterioration would possibly initiate either in the steel reinforcement at mid span or inside the mass of the concrete at a location near the supports. Hence, this simple structure features two interesting characteristics related to its performance in terms of fatigue. The first is that, because of its short influence length, it experiences a very high number of stress cycles of relatively high stress amplitudes. The second is that it represents a real case where fatigue of concrete itself may be the critical factor that limits the safe service life of the structure. The fatigue behavior of unreinforced concrete in shear has very little been investigated [3].
The aim here is to investigate whether there is a practical limit in the service life of structures of this kind under the current traffic regime and how this limit is affected under various scenarios for the evolution of the railway traffic characteristics in the future.

References

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