

Distributed optical fiber sensors for integrated monitoring of railway infrastructures

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Abstract. We describe the application of a distributed optical fiber sensor based on stimulated Brillouin scattering, as an integrated system for safety monitoring of railway infrastructures. The strain distribution was measured statically and dynamically along 60 meters of rail track, as well as along a 3-m stone arch bridge. We show that, gluing an optical fiber along the rail track, traffic monitoring can be performed in order to identify the train passage over the instrumented sector and determine its running conditions. Furthermore, dynamic and static strain measurements on a rail bridge are reported, aimed to detect potential structural defects. The results indicate that distributed sensing technology represents a valuable tool in railway traffic and safety monitoring.

Keywords: optical fiber measurements; brillouin scattering; structural health monitoring

1. Introduction

The demand for safe and cost-effective train operation in the railroad transportation industry has dramatically increased in the last years. An efficient railway maintaining and inspection technique may provide information about the rail and wheel defects (Nielsen and Johansson 2000, Wilcox *et al.* 2003, Lee *et al.* 2009, Rizzo *et al.* 2010). In the field of railway infrastructure monitoring, structural health monitoring (SHM) is a key element of industrial businesses. Standard inspection techniques may fail in revealing defects or unusual features, and some components may not receive close up examination if, for example, access is difficult or operating conditions do not permit. Distributed optical fiber sensing techniques allow distributed temperature and strain measurements to be captured in real time over lengths of a few meters to tens of kilometers (Bao and Chen 2011). A permanently installed optical fiber provides continuous information about the status of the structure during its whole life cycle, thereby offering a unique opportunity in long-term SHM (Minardo *et al.* 2012, Ko and Ni 2005).

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- evaluation of compact FBG sensor system for structural health monitoring applications”, *Sens. Actuat. A - Phys.*, **151**(2), 107-121.
- Ko, M. and Ni, Y.Q. (2005), “Technology developments in structural health monitoring of large-scale bridges”, *Eng. Struct.*, **27**(12), 1715-1725.
- Lee, C.M., Rose, J.L. and Cho, Y. (2009), “A guided wave approach to defect detection under shelling in rail”, *NDT & E Int.*, **42**(3), 174-180.
- Minardo, A., Bernini, R., Amato, L. and Zeni, L. (2012), “Bridge monitoring using Brillouin fiber-optic sensors”, *IEEE Sens. J.*, **12**(1), 145-150.
- Minardo, A., Porcaro, G., Giannetta, D., Bernini, R. and Zeni, L. (2013), “Real-time monitoring of railway traffic using slope-assisted Brillouin distributed sensors”, *Appl. Optics.*, **52**(16), 3770-3776.
- Nielsen, J.C.O. and Johansson, A. (2000), “Out-of-round railway wheels-a literature survey”, *Proceedings of the Institution of Mechanical Engineers, Part F: J. Rail and Rapid Transit*, **214**(2), 79-91.
- Niklès, M., Thévenaz, L. and Robert, P.A. (1997), “Brillouin gain spectrum characterization in single-mode optical fibers”, *IEEE J. Lightw. Technol.*, **15**(10), 1842-1851.
- Peled, Y., Motil, A., Yaron, L. and Tur, M. (2011), “Slope-assisted fast distributed sensing in optical fibers with arbitrary Brillouin profile”, *Opt. Express.*, **19**(21), 19845-19854.
- Peled, Y., Motil, A., Kressel, I. and Tur, M. (2013), “Monitoring the propagation of mechanical waves using an optical fiber distributed and dynamic strain sensor based on BOTDA”, *Opt. Express.*, **21**(9), 10697-10705.
- Rizzo, P., Cammarata, M., Bartoli, I., Lanza di Scalea, F., Salamone, S., Coccia, S. and Philips R. (2010), “Ultrasonic guided waves-based monitoring of rail head: laboratory and field tests”, *Adv. Civil Eng.*, **210**, <http://dx.doi.org/10.1155/2010/291293>.
- Valis, T., Hogg, D., Measures, R.M. (1992), “Thermal apparent-strain sensitivity of surface-adhered, fiber-optic strain gauges”, *Appl. Optics.*, **31**(34), 7178-7179.
- Wilcox P., Pavlakovic B., Evans M., Vine K., Cawley P., Lowe M., Alleyne D. (2003), “Long range inspection of rail using guided waves”, *Rev. Prog. Quant. Nondestruct. Eval.*, **22**, 236-243.