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DOI:

[10.3390/proceedings2161147](https://doi.org/10.3390/proceedings2161147)

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Document Version

Publisher's PDF, also known as Version of record

Citation for published version (Harvard):

Freimanis, A, Kaewunruen, S & Ishida, M 2018, 'Peridynamics Modelling of Rail Surface Defects in Urban Railway and Metro Systems', *Proceedings*, vol. 2, no. 16. <https://doi.org/10.3390/proceedings2161147>

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Checked for eligibility 14/09/2018

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Proceedings 2018, 2(16), 1147; <https://doi.org/10.3390/proceedings2161147>

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Peridynamics Modelling of Rail Surface Defects in Urban Railway and Metro Systems [†]

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[†] Presented at 2018 International Symposium on Rail Infrastructure Systems Engineering (i-RISE 2018), Brno, Czech Republic, 5 June 2018.

Published: 14 September 2018

Rail squats and studs, which are one of critical rail surface defects, are typically classified as the propagation of any cracks that have grown longitudinally through the subsurface. Some of the cracks could propagate to the bottom of rails transversely, which have branched from the initial longitudinal cracks with a depression of rail surface. The rail defects are commonly referred to as ‘squats’ when they were initiated from damage layer caused by rolling contact fatigue, and as ‘studs’ when they were associated with white etching layer caused by the transform from pearlitic steel due to friction heat generated by wheel sliding or excessive traction. Such above-mentioned rail defects have been often observed in railway tracks catered for either light passenger or heavy freight traffics and for low, medium or high speed trains all over the world for over 60 years except some places such as sharp curves where large wear takes place under severe friction between wheel flange and rail gauge face. It becomes a much-more significant issue when the crack grows and sometimes flakes off the rail (by itself or by insufficient rail grinding), resulting in a rail surface irregularity. Such rail surface defect induces wheel/rail impact and large amplitude vibration of track structure and poor ride quality. In Australia, Europe and Japan, rail squats/studs have occasionally turned into broken rails [1–12].

This study is the word first to establish and demonstrate a novel state-based peridynamics modelling technique that is able to define and predict crack propagation from rail surface defects commonly found in urban railway and metro systems. The root cause and preventive solution to this defect are still under investigation from the fracture mechanics and material sciences point of view. Some patterns of squat/stud development related to both of curve and tangent track geometries have been observed, and squat growth has also been monitored for individual squats using ultrasonic mapping techniques. This paper highlights peridynamics modeling of squat/stud distribution and its growth [13–17]. Squat/stud growth has been measured in the field using the ultrasonic measurement device on a grid applied to the rail surface. The depths of crack paths at each grid node form a three dimensional contour of rail squat crack. The crack propagation of squats/studs is modelled using peridynamics. The modeling and field data is compared to evaluate the effectiveness of peridynamics in modelling rail squats as shown in Figure 1.

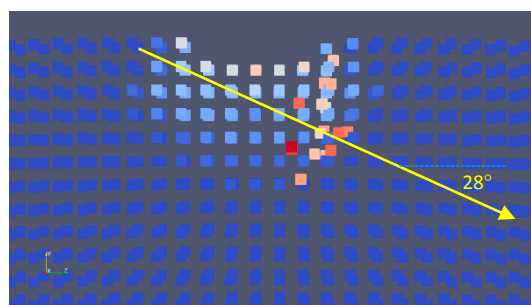


Figure 1. Peridynamics crack propagation of rolling contact fatigue defect.

Acknowledgments: The authors are also sincerely grateful to the European Commission for the financial sponsorship of the H2020-RISE Project No. 691135 “RISEN: Rail Infrastructure Systems Engineering Network”, which enables a global research network that tackles the grand challenge of railway infrastructure resilience and advanced sensing in extreme environments (www.risen2rail.eu) [18]. The first author is grateful to Erasmus+ for the financial support for his research internship at the University of Birmingham. The second author wishes to thank the Australian Academy of Science and the Japan Society for the Promotion of Sciences for his Invitation Research Fellowship (Long-term), Grant No. JSPS-L15701 at the Railway Technical Research Institute and The University of Tokyo, Japan.

References

1. Kaewunruen, S. Identification and prioritization of rail squat defects in the field using rail magnetisation technology. *Proc. SPIE Int. Soc. Opt. Eng.* **2015**, *9437*, 94371H, doi:10.1117/12.2083851.
2. Kaewunruen, S. Discussion of “Field Test Performance of Noncontact Ultrasonic Rail Inspection System” by Stefano Mariani, Thompson Nguyen, Xuan Zhu, and Francesco Lanza di Scalea. *J. Transp. Eng. Part A Syst.* **2018**, *144*, 07018001, doi:10.1061/JTEPBS.0000134.
3. Kaewunruen, S.; Ishida, M. Field monitoring of rail squats using 3D ultrasonic mapping technique. *J. Can. Inst. Non-Destr. Eval.* **2014**, *35*, 5–11.
4. Kaewunruen, S.; Ishida, M. Rail squats: Understand its causes, severity, and non-destructive evaluation techniques. In Proceedings of the 20th National Convention on Civil Engineering, Pattaya, Thailand, 8–10 July 2015; Best Paper Award in Infrastructure Engineering. Available online: https://works.bepress.com/sakdirat_kaewunruen/56/ (accessed on 1 August 2017).
5. Kaewunruen, S.; Ishida, M. In Situ Monitoring of Rail Squats in Three Dimensions Using Ultrasonic Technique. *Exp. Tech.* **2016**, *40*, 1179–1185.
6. Kaewunruen, S.; Remennikov, A.M. Dynamic Properties of Railway Track and Its Components: Recent Findings and Future Research Direction. *Insight—Non-Destr. Test. Cond. Monit.* **2010**, *52*, 20–22.
7. Kaewunruen, S.; Ishida, M.; Marich, S. Dynamic wheel-rail interaction over rail squat defects. *Acoust. Aust.* **2015**, *43*, 97–107.
8. Kaewunruen, S.; Remennikov, A.M. Current state of practice in railway track vibration isolation: An Australian overview. *Aust. J. Civ. Eng.* **2016**, *14*, 63–71.
9. Kaewunruen, S.; Remennikov, A.M. Sensitivity analysis of free vibration characteristics of an in situ railway concrete sleeper to variations of rail pad parameters. *J. Sound Vib.* **2006**, *298*, 453–461.
10. Kaewunruen, S.; Remennikov, A.M. Progressive failure of prestressed concrete sleepers under multiple high-intensity impact loads. *Eng. Struct.* **2009**, *31*, 2460–2473.
11. Kaewunruen, S.; Chiengson, C. Railway track inspection and maintenance priorities due to dynamic coupling effects of dipped rails and differential track settlements. *Eng. Fail. Anal.* **2018**, *93*, 157–171.
12. Remennikov, A.M.; Kaewunruen, S. A review of loading conditions for railway track structures due to train and track vertical interaction. *Struct. Control Health Monit.* **2008**, *15*, 207–234.
13. Silling, S.A. Reformulation of Elasticity Theory for Discontinuities and Long-Range Forces. *J. Mech. Phys. Solids* **2000**, *48*, 175–209.
14. Silling, S.A.; Askari, E. A Meshfree Method Based on the Peridynamic Model of Solid Mechanics. *Comput. Struct.* **2005**, *83*, 1526–1535.
15. Silling, S.A.; Epton, M.; Weckner, O.; Xu, J.; Askari, E. Peridynamic States and Constitutive Modeling. *J. Elast.* **2007**, *88*, 151–184.
16. Silling, S.A.; Lehoucq, R.B. Peridynamic Theory of Solid Mechanics. *Adv. Appl. Mech.* **2010**, *44*, 73–168.

17. Silling, S.; Askari, A. Peridynamic Model for Fatigue Cracks SANDIA REPORT SAND2014-18590. *Albuquerque* **2014**. Available online: <http://docs.lib.purdue.edu/ses2014/mss/cfm/22/> (accessed on 1 August 2018).
18. Kaewunruen, S.; Sussman, J.M.; Matsumoto, A. Grand challenges in transportation and transit systems. *Front. Built Environ.* **2016**, *2*, 4, doi:10.3389/fbuil.2016.00004.



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