Bicycle Roller Chain Efficiency Degradation

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Introduction

As cyclists continually strive to maximize their performance, lubrication plays a pivotal role in maintaining a well-functioning and efficient drive train. Understanding when, why and how chain efficiency decreases is crucial, as it enables cyclists to determine the optimal application cycle for chain lubrication.

Methods

Previous research efforts have led to the development of a specialized test rig designed for assessing bicycle smart home trainers [1], [2]. Building upon this foundation, the test rig was extended to evaluate the efficiency of bicycle drive systems (as depicted in **Figure 1**). The inspiration for this design was drawn from various authors [3]–[9]. The test rig employed a motor to transmit rotational power through the extracted bicycle drive train system and into a controllable magnetic brake. Two in-line torque transducers were strategically placed before and after the drive train. These transducers, in conjunction with a rotary encoder, measured the power before and after the drive train, thereby enabling the calculation of power loss during transmission.

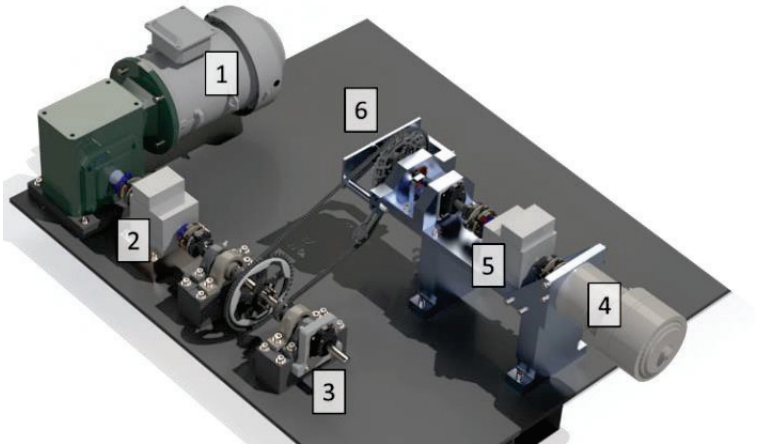

Figure 1 Chain testing rig with major components: 1) 3.7Kw Motor 2) Input In-line torque transducer 3) Rotary encoder 4) Controllable magnetic brake 5) Output In-line torque transducer 6) Derailleur and cassette

The test rig analysed chain efficiency under a variety of conditions. For endurance testing, a cadence of 100rpm at 23.8Nm with a 42:17 gear ratio, producing 250W, was chosen. This corresponds to a bike speed of approximately 32 km/h when ascending a road with a 0.4% gradient, a common scenario for cyclists. To investigate the chain efficiency degradation over time, a new chain was stripped and submersion waxed with 160C melt paraffin, and repeated 6hr endurance tests were performed.

Results & Discussion

Results from repeated endurance testing are presented in **Figure 2.** The same 6hr test was repeated for 135 hours of runtime, with the mean efficiency plotted as the trendline. The findings reveal that the chain efficiency followed a distinctive trend, initially performing well

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for approximately 80 hours before declining in efficiency. By 135 hours, efficiency had dropped by 2.5% to 94% and was still decreasing. The inflection point in this degradation curve may signify a critical juncture at which a substantial volume of lubricant has been displaced from the frictional interface, leading to the decline in efficiency. This observation is part of a larger investigation in which the physical and chemical properties of the chain-lubricant system including surface tension, viscosity and chain articulation angle are being investigated for their influence on chain efficiency and longevity.

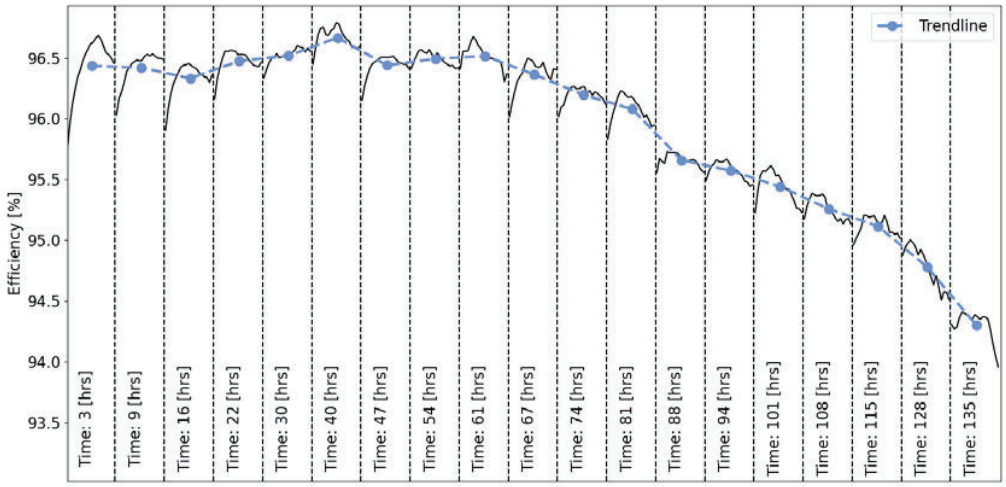

Figure 2 Chain efficiency of repeated 6hr tests, with mean efficiency trendline

Acknowledgments

We would like to thank Purdue's Ray Ewry Sports Engineering Center for their collaboration and financial support for this project. The authors would also like to acknowledge the cycling parts accessory company SILCA for providing chains and lubricants for this study.

References

[1] T. Dowd, J. Miller, D. Heflin, J.-A. Mansson, and W. Sweldens, “Bicycle Trainer Homologation Apparatus,” 63/122,449, 2020.

[2] D. Heflin, J. Miller, T. Dowd, Mm. Rogers, A. ; Krasilnikau, and J.-A. Mansson, “Smart Trainer Homologation for Cycling: Homologation and Analysis,” *Sport. Eng.*, 2022.

[3] C. J. Lodge and S. C. Burgess, “Experimental Measurements of Roller Chain Transmission Efficiency,” in *Proceedings of the International Conference on Gearing, Transmissions, and Mechanical Systems*, 2000, pp. 603–612.

[4] C. J. Lodge and S. C. Burgess, “A Model of the Tension and Transmission Efficiency of a Bush Roller Chain,” *Proc. Inst. Mech. Eng. Part C J. Mech. Eng. Sci.*, vol. 216, no. 4, pp. 385–394, Apr. 2001, doi: 10.1243/0954406021525179.

[5] A. Egorov, K. Kozlov, and V. Belogusev, “A method for evaluation of the chain drive efficiency,” *Istraz. i Proj. za privredu*, vol. 13, no. 4, pp. 277–282, 2015, doi: 10.5937/jaes13-9170.

[6] S. P. Zhang and T. O. Tak, “Efficiency estimation of roller chain power transmission system,” *Appl. Sci.*, vol. 10, no. 21, pp. 1–13, 2020, doi: 10.3390/app10217729.

[7] M. D. Kidd, “Bicycle chain efficiency,” Heriot-Watt University, 2000.

[8] C. Kyle and F. Berto, “The mechanical efficiency of bicycle derailleur and hub-gear transmissions Technical notes,” *Hum. Power*, vol. 52, pp. 3–10, 2001.

[9] J. B. Spicer, C. J. K. Richardson, M. J. Ehrlich, J. R. Bernstein, M. Fukuda, and M. Terada, “Effects of Frictional Loss on Bicycle Chain Drive Efficiency,” *J. Mech. Des.*, vol. 123, no. 4, pp. 598–605, Dec. 2001, doi: 10.1115/1.1412848.

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