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Conference Abstract

Big Sprockets and Small-Pitch Chains: Advancements in Transmissions for Olympic Track Cycling

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Abstract:

Introduction It is well known that cycling is a sport in which the performance of the equipment is critical to the outcome of competitions. At the elite level, winning margins are very small. For example, in the men's team pursuit at the Tokyo 2020 Olympics, the winning margin was 0.166 seconds against a time of 3 minutes 42 secs; in sprint events, the margins can be even smaller, the women's individual sprint at the Rio 2016 Olympics was won by 0.016s and 0.004s in the two races of the final. Considerable effort is made by internationally competitive teams to ensure the best performance from athletes and equipment. The work described herein highlights some recent developments in the field of track bicycle transmissions, specifically related to the sizing and geometry of the chains and sprockets. The impact of these studies was quantified using a very accurate dynamometer and subsequently demonstrated in international competitions.

The main source of power loss in a chain drive is due to friction in the pin-bush-roller interface; contact pressure and articulation angle both contribute to the total amount of energy lost. The motion in a chain link has been shown (Wragge-Morley, Yon, Lock, Alexander, & Burgess, 2018) to display both a rocking and a sliding component, influenced by the friction at the contact point and the geometry of the contacting surfaces as previously hypothesised (Lodge & Burgess, 2002). In a cycling application, where the chain is used as a step-up transmission, the majority of the power loss will be at the rear sprocket, where the speeds and articulation angles are highest.

Materials and Methods: Power transmission efficiency is a key element in ensuring riders have a competitive machine. When winning margins are below 1% of the duration of sprint events and 0.1% of pursuit events, a 0.1% or 0.2% increase in drivetrain efficiency can make a significant contribution to the overall performance. The hypothesised performance gains for a 0.25% transmission efficiency improvement over a 97% baseline is presented in Table 1; a 4km endurance event and a 375m sprint are considered. The rider and machine are modelled based on assumptions relating to power and aerodynamics and do not represent a specific rider or bicycle. Note that the benefit possible for the same percentage improvement from a higher baseline will be relatively slightly smaller as the aerodynamic resistance dominates an increase in speed.

Furthermore, an empirical study has been carried out using the dynamometer described in (Barnaby, 2023) comparing the performance of transmissions of the same gear ratio (1:4) and centre-centre distance, but using differently scaled chainrings and sprockets, a mid-range, off-the-shelf 0.5″ pitch chain was used. The transmission was tested across 49 points to cover the full map of input values from 70 to 130 rpm cadence and 20 to 150 Nm crank torque. Additionally, a twice per revolution torque fluctuation representing the power delivery of a cyclist was applied in these tests.

Results: From the perspective of the sporting application, many track cyclists have historically favoured the use of smaller hardware due to reduced mass; however this effect is negligible compared to the efficiency gain, referring again to Table 1. This computation should be compared with the measured results for power transmission efficiency in Figure 1 and Figure 2, which show the power transmission efficiency improvement achieved by moving to larger sprockets.

Table 1. Gain associated with a 0.25% improvement in transmission efficicieny for example track cycling events.

Efficiency Improvement	Men's Endurance		Women's Endurance		Men's Sprint		Women's Sprint	
Gain	(secs)	Dist. (m)	(secs)	Dist. (m)	(secs)	Dist. (m)	(secs)	Dist. (m)
0.25	0.24	3.76	0.19	2.82	0.024	0.41	0.025	0.39

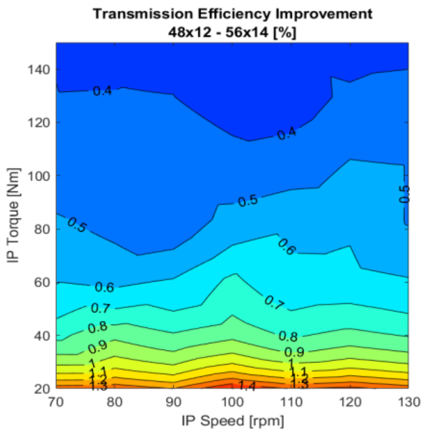

Figure 1. Percentage improvement in power transmission efficiency for 56:14 over 48T:12.

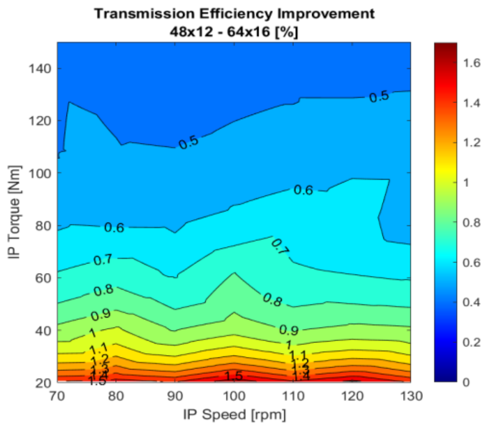

Figure 2. Percentage improvement in power transmission efficiency for 64:16 over 48:12.

Conclusions: It has been postulated (Burgess, 1998) that there are numerous benefits from the use of larger chainrings, most notably the reduction in chain tight-span tension thence contact patch force. A more subtle effect of using sprockets with larger numbers of teeth is the reduction of articulation angle leading to a reduction in sliding contact friction, and also the reduction in tight span excitation due to polygonal action of the sprocket. It has been shown experimentally that the presence of tight span vibration in a bicycle transmission has a detrimental effect on power transmission efficiency (Barnaby, 2023). Furthermore, there is some evidence to suggest that the presence of vibration in the driveline could have a detrimental effect of physiological performance (Bongiovanni, Hagbartht, & Stjernbergt, 1990).

Keywords: Transmission, Efficiency, Model, Losses, Testing, Dynamometer

References

Barnaby, G. C. (2023). Experimental and modelling methods for high-accuracy performance characterisation of chain drives. University of Bristol Student Thesis.

Bongiovanni, L. G., Hagbartht, K. E., & Stjernbergt, L. (1990). Prolonged Muscle Vibration Reducing Motor Output in Maximal Voluntary Contractions in Man. Journal of Physiology, 423, 15-26.

Burgess, S. (1998). Improving cycling performance with large sprockets. Sports Engineering, 1, 107-113.

Lodge, C. J., & Burgess, S. C. (2002). A model of the tension and transmission efficiency of a bush roller chain. Proceedings of the Institution of Mechanical Engineers Part C, Journal of Mechanical Engineering Science, 216(C4), 385-394.

Wragge-Morley, R., Yon, J., Lock, R., Alexander, B., & Burgess, S. C. (2018). A novel pendulum test for measuring roller chain efficiency. Measurement Science and Technology, 29.