Analysis of Static Stress in a Bicycle Chain Plate

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Abstract

INTRODUCTION: Bicycles are popular and inexpensive means of transportation. In Germany for instance there are 1.84 bicycles per household and 9 % of all transportation is accomplished by bicycle [1]. The chain drive is an essential component for efficient bicycle operation. Chain efficiency can reach up to 98 % [2]. In addition to efficiency, chain durability is important for chains [3]. With increasing numbers of sprockets in a cassette the chain dimensions have to be adjusted. In this work the impact of the geometrical scaling on the mechanical stress is investigated. Smaller chains result in smaller thickness of the plates. The resulting stress increase is analyzed for 8-, 9- and 10 speed chains (Figure 1).

USE OF COMSOL: The model is set up based on the Solid Mechanics interface. For numerical efficiency a 2D quarter geometry of the chain plate is used with the plane stress approximation (no stress in direction of the plate thickness). The following boundary conditions are configured (Figure 2): Symmetry, Roller, Contact, Spring Foundation and Body Load. A contact model is used to induce the load on the chain plate. Plastic deformation is taken into account. The Plasticity sub-node below Linear Elastic Material is enabled accordingly. The chosen configuration is reported. The mesh follows the recommendations for contact modeling. For numerical stability load ramping is used.

RESULTS: Figure 3 shows an example of the simulated effective plastic strain for the 9-speed chain geometry. It displays the situation after relief at the end of several load cycles. The maximum value is 2.75 %. It is consistent with the assumption of Small plastic strains in the Plasticity Model.

Examples of simulated force-displacement characteristics are shown in Figure 4. The displayed data refer to the full geometry and total chain force and are core results of this work. The curves show the results of two load cycles of each of the investigated chain generations. Data for the first load cycle are drawn with colored solid lines, while the second cycle data is indicated by dotted black lines. In all cases the second cycle data falls together with the relief path of the first cycle data. Therefore, a third load cycle would not cause a different situation and simulating two cycles is sufficient.

Referencing to the maximum wear measurement per plate (0.075 mm [2]) the contribution of

plastic deformation can be calculated from the data in Figure 4. It is approximately 15 % for 8-speed, 50% for 9-speed and 500 % for 10 speed chain. Only the 8-speed value is acceptable. The paper reports simulations with adjusted material properties of common high tension carbon steel variants [4] which enable reasonable performance also for the 9- and 10-speed chain.

CONCLUSION: Using the Solid Mechanics interface, a model was set up to analyze static stress in bicycle chains for varied geometries related to three technology generations. The results suggest that common high tension steel can still be used for modern chains where scaled geometries lead to increased stress levels.

Reference

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[3] Shoji Noguchi et al., Static Stress Analysis of Link Plate of Roller Chain using Finite Element Method and Some Design Proposals for Weight Saving, Journal of Advanced Mechanical Design Systems and Manufacturing, Vol.3, No. 2,(2009)

[4] Lucefin Group, 36NiCrMo16 – Technical card, Available from: [29 July 2015]

Figures used in the abstract

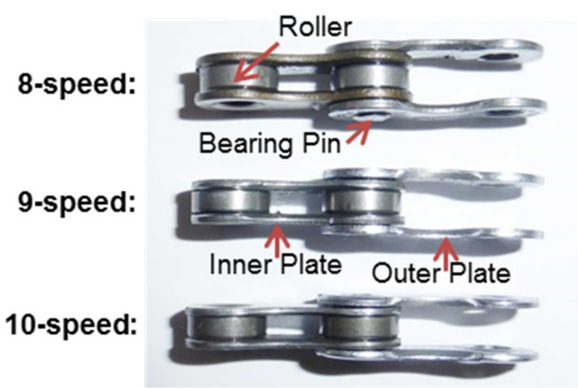

Figure 1: Three investigated chain generations.

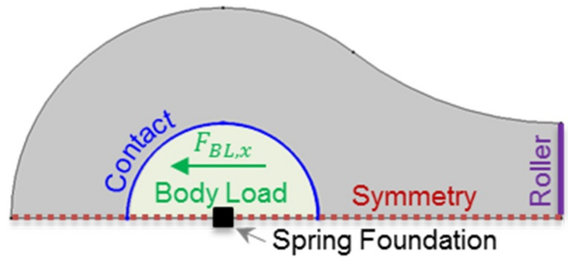

Figure 2: Quarter geometry with boundary conditions.

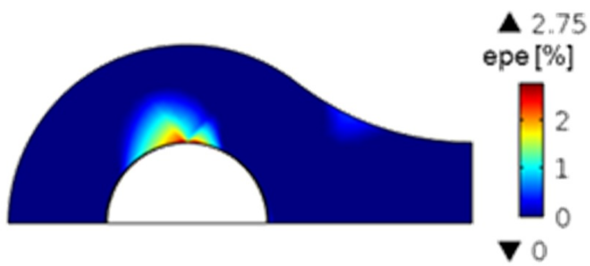

Figure 3: Effective plastic strain for the 9 speed chain geometry after relief at the end of a load cycle.

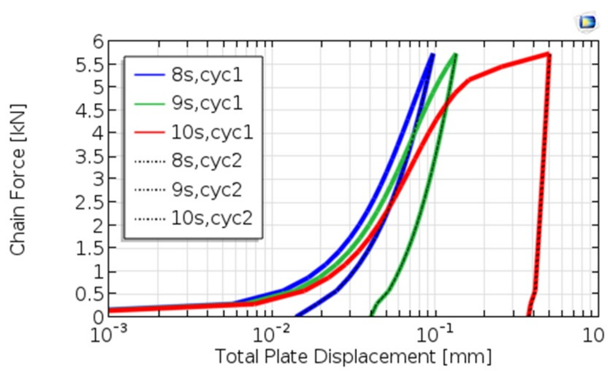

Figure 4: Force-displacement curves for the investigated chain variants.