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Development of a multi-directional rating test method for bicycle frame stiffness

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Abstract

The methods for determining the bicycle frame stiffness exist in many forms. Because the stiffness measuring method is not standardized, each bicycle magazine or bicycle constructer uses his own test configuration. This leads to a wide variety of setups; they differ in many aspects such as applied load, boundary conditions and frame deflection measurement. To clarify some shortcomings in frame testing, a multi-directional rating test method for bicycle frame stiffness has been developed. The proposed test rig design considers different aspects that should be taken into account when measuring the bicycle frame stiffness.

At first, it is important to eliminate perturbing side effects that influence the stiffness value of the bicycle frame. FE analysis revealed that using 'very stiff' boundary conditions to constrain certain degrees of freedom should be handled with the utmost caution. Using these non-rigid boundary conditions affects the bicycle frame deflection significantly. Therefore, prior to stiffness testing, the contribution of the test rig compliance should be estimated. It is advised to limit its estimated influence below 2 %. Hysteresis effects due to stick-slip and friction are avoided by omitting fixed boundary conditions and eliminating the friction force when using a pulley mechanism; if not errors up to 11 % are observed. It is recommended to use a rolling contact to constrain translation motion and to measure the force acting on the frame without other mechanisms between the force sensor and the bicycle frame. Another issue is the effect of the head tube bearing type and the preloading torque. The industrial bearings reduce the frame stiffness up to 19 % when comparing with steel bearing replicas. It is the operator's decision to test bicycle frames with or without industrial bearings for stiffness measurements. Though, steel bearings are advised for mutual frame comparison since this avoids discussion about the differences among industrial bearings. The overall accuracy of the test result is expressed as percentage deviation on the 95 % confidence interval and includes both the influence of the operator and the sensors. To detect small changes between results from different frames, a percentage value of 2 % or less is desired.

The selection of stiffness configurations is based on the major load components acting at the head tube, the bottom bracket and the rear-dropout. The bracket- and torsion stiffness are replaced with a specific classification of the test setup. The directional frame stiffness is as such assessed for individual load cases: (i) the in-plane vertical and horizontal stiffness of the bottom-bracket and rear-dropout, (ii) the transversal or out-of-plane stiffness of the bottom bracket and (iii) the torsion stiffness with or without the contribution of the rear-triangle of the bicycle frame. As such is detailed information available for the bicycle constructor to modify the design and for the cyclist when comparing the stiffness characteristics of different frame types.

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