Proceedings of Engineering and Technology Innovation, vol. 4, 2016, pp. 43 - 45

Structural Analysis of Existing Multi-Speed Transmission Hubs of Bicycles

Yi-Chang Wu *

Department of Mechanical Engineering, National Yunlin University of Science & Technology, Yunlin, Taiwan.

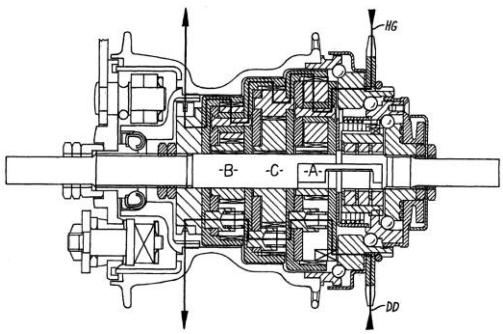
Received 01 February 2016; received in revised form 10 March 2016; accepted 02 April 2016

Abstract

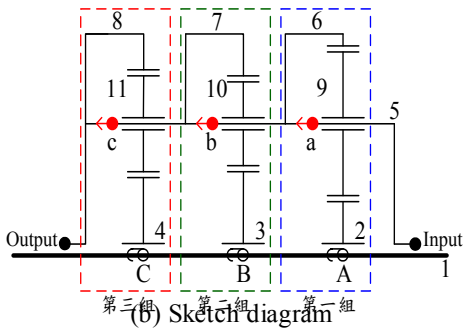
This paper presents the analysis of topological structure of multi-speed transmission hubs for bicycles. Three existing transmission hubs with 8-speed, 11-speed and 12-speed are introduced. The topological structure of each gear mechanism, which is the main body of a transmission hub, is analyzed. The degrees-of-freedom (DOF) of the transmission hub is calculated by the Kutzbach's equation. The related clutching sequence table for each transmission hub is also listed.

Keywords: structural analysis, multi-speed, transmission hub, bicycle

1. A Sturmey-Archer 8-Speed Transmission Hub



(a) Cross-section



(b) Sketch diagram

Clutch / Gear	A	B	C	a	b	c
1st Gear				X	X	X
2nd Gear	X				X	X
3rd Gear			X	X	X	
4th Gear		X		X		X
5th Gear	X		X		X	
6th Gear	X	X				X
7th Gear		X	X	X		
8th Gear	X	X	X			

(c) Clutching sequence table

Fig. 1 Sturmey-Archer 8-speed transmission hub

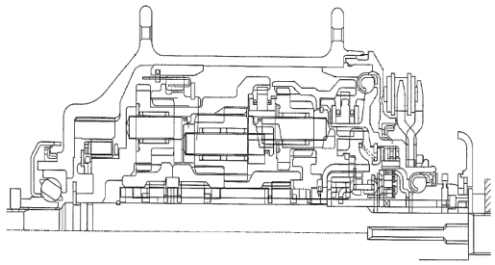
Figs. 1(a) and 1(b) show the cross-section and sketch diagram of the Sturmey-Archer 8-speed transmission hub [1], respectively. It is a gear mechanism consists of 11 links, 6 gear pairs and 10 turning pairs. According to the Kutzbach's criterion, the degrees-of-freedom (DOF) of this gear mechanism is: DOF = $3(N-1)-2J_1-1J_2$ = $3(11-1)-2*10-1*6$ = 4. Because it is a 4-DOF mechanism, four constraints are required for precise controlling this mechanism. Except for an input constraint, three additional constraints should be provided, which can be achieved by controlling the engagement of mechanical clutches within the gear mechanism. As can be seen in the clutching sequence table shown in Fig. 1(c), three mechanical clutches are activated at each gear stage.

2. A Shimano 11-Speed Transmission Hub

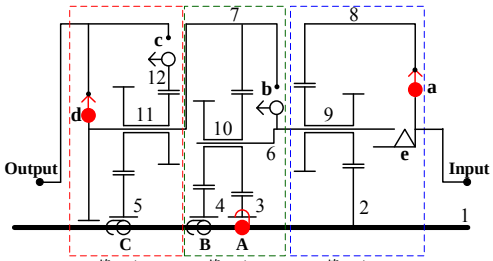
Figs. 2(a) and 2(b) show the cross-section and sketch diagram of the Shimano 11-speed transmission hub [2], respectively. It consists of three sets of compound planetary gear trains, which is a 12-link gear mechanism with 7 gear pairs and 11 turning pairs. According to the Kutzbach's criterion, the DOF of this gear mechanism is: DOF = $3(N-1)-2J_1-1J_2$ = $3(12-1)-2*11-1*7$ = 4. For this

* Corresponding author. Email: wuyc@yuntech.edu.tw

transmission hub, 8 mechanical clutches are installed for controlling the power-flow path at each gear stage. Fig. 2(c) depicts the clutching sequence table of this transmission hub.



(a) Cross-section



(b) Sketch diagram

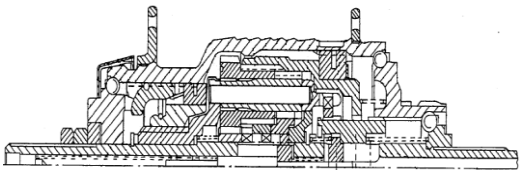
PGT	I		II			III		
Clutch / Gear	a	e	A	B	b	C	c	d
1st Gear	X				X			X
2nd Gear	X				X	X	X	
3rd Gear	X		X					X
4th Gear	X			X				X
5th Gear	X		X			X	X	
6th Gear	X			X		X	X	
7th Gear		X			X	X	X	
8th Gear		X	X					X
9th Gear		X		X				X
10th Gear		X	X			X	X	
11th Gear		X?		X		X	X	

(c) Clutching sequence table

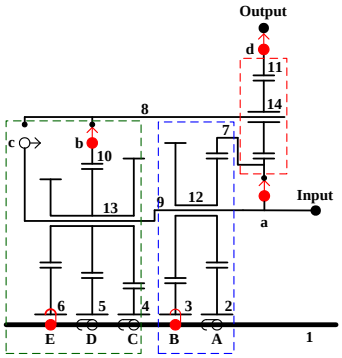
Fig. 2 Shimano 11-speed transmission hub

3. A Sachs 12-Speed Transmission Hub

Figs. 3(a) and 3(b) show the cross-section and sketch diagram of the Sachs 12-speed transmission hub [3], respectively. It consists of two sets of compound planetary gear trains as transmission units and one basic planetary gear train as a differential unit. This is a 14-link gear mechanism with 9 gear pairs and 13 turning pairs. According to the Kutzbach's criterion, the DOF of this gear mechanism is: DOF = $3(N-1)-2J_1-1J_2 = 3(14-1)-2*13-1*9 = 4$. For this transmission hub, 8 mechanical clutches are installed for controlling the power-flow paths of the two sets of transmission units. Fig. 3(c) shows the clutching sequence table of this transmission hub.



(a) Cross-section



(b) Sketch diagram

	PGT I			PGT II				
Clutch / Gear	A	B	a	C	D	E	b	c
1st Gear	X							X
2nd Gear		X						X
3rd Gear			X					X
4th Gear	X			X			X	
5th Gear		X		X			X	
6th Gear			X	X			X	
7th Gear	X				X		X	
8th Gear		X			X		X	
9th Gear			X		X		X	
10th Gear	X					X	X	
11th Gear		X				X	X	
12th Gear			X			X	X	

(c) Clutching sequence table

Fig. 3 Sachs 12-speed transmission hub

4. Conclusions

Based on the above analysis, we can conclude that the main body of a multi-speed transmission hub used for bicycles is usually a complex planetary gear train for providing with several forward gears. Mechanical clutches,

especially for one-way clutches, are employed on coaxial links, i.e., the sun gears, carriers and ring gears, for correctly guiding the power-flow path at each gear stage. The number of activated clutches at each gear stage is related to the DOF of the planetary gear mechanism.

Acknowledgment

The author is grateful to the Ministry of Science & Technology (Taiwan, R.O.C) for supporting this research under Grants No. MOST 104-2628-E-224-001-MY3.

References

[1] Rickels & SRAM, A multi-speed hub gear, World Patent, 01/92094, 2001.
[2] Shimano Inc., Bicycle hub transmission, U. S. Patent, 2009/0023542, 2009.
[3] M. Gerhard, Multi-speed hub for bicycles, U. S. Patent, 5527230, 1996.