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TRANSMISSION SYSTEM DESIGN FOR A MOUNTAIN BIKE WITH 2X2 TRACTION

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Abstract: *Cycling is a sport that has undergone significant growth in recent decades. Competitors seek new technologies in order to better their performance. The steep slopes and slippery slopes are the biggest problems faced by cyclists due to the drive wheel slip. This study aims to develop a mechanical system capable of transmitting traction of the rear wheel to the front wheel, offsetting losses with slip. Applying the concept of 4x4 off road vehicle, we developed a drive system 2x2. The project used a 3D modeling software and calculations used conventional mathematical methods. The drive system was divided into 4 sub-systems consisting of gears and cardan joints. Calculations were made of the transmission ratio, torque, power and speed. The results showed positive regarding the operation and applicability of the transmission system requiring a review of the materials used for mass reduction assembly.*

Keywords: *Full Traction, Drive system, Mountain bike*

1. INTRODUCTION

Designed by Leonardo da Vinci around the year 1490, the bicycle is considered the most widely used form of transport in the world. Throughout history has undergone several adaptations motivated by cultural and economic factors, gaining attention and popularity. Considered a relatively simple vehicle comprises two wheels attached to a frame, moved by the user himself via pedal effort.

The history of the Mountain Bike had its beginnings in the late 1970s in the mountains of California when asphalt cyclists ventured into the land, giving rise to a new type of cycling. This modality needed more sturdy frames, more efficient brakes, suspension and tires more appropriate, setting the bike model called Mountain Bike. Its use in competitions has extensive history and shows constantly evolving into its components seeking performance boost for athletes (Webventure, 2015).

Because of the diverse natural ground conditions as mud, loose stones, sand, gravel, ground cover and steep slopes, the Mountain Bike suffers from low grip of the front tire which normally does not receive torque. This fact causes loss of stability which creates downside risk for the athlete and decreased performance. This paper aims to design an integral transmission system 2x2, applied to Mountain Bike, seeking greater stability, torque control applied to the wheels, improved security and performance to the athlete.

Some systems transmit torque between the front and rear wheels of a mountain bike are shown in the literature. These include models of the JEEP (SADAPIC, 2014) and SUBARU Dual Power (Dorotheum, 2014), but these models have a high cost. This project aims to develop a low-cost system for transmitting torque between the wheels of the bicycle.

2. METHODS

2.1. Design of the torque transmission system

A system capable of transmitting torque of the rear wheel to the front wheel was designed (Fig. 1) (Juvinall, 1991; Norton 2000). The transmission is made by gears and shafts. It was used as a reference Mountain bike with 27 speeds.

Figure 1. (a) Representation of the proposed system. (b) Moutain Bike mounted with the proposed system.

The 2x2 drive system was divided into four subsystems: Rear transmission; Transmission shafts, steering system and front Transmission.

2.1.1 - Rear Transmission

The Rear Transmission is composed by the wheel hub, a pair of bevel gears and fixings, as shown in Fig. 2. One gear is attached to the rear axle and the other is attached in one of the shafts of the system Transmission Shafts.

Figure 2. Details of the rear transmission system.

2.1.2 - Transmission shafts

The Transmission shafts system consists of five sections of solid steel shafts and two universal joints (Fig. 3).

Figure 3. Details of the shafts for transmission.

2.1.3 - Steering System

The steering system consists of a pair of bevel spur gears for a gear train containing three cylindrical gears helical teeth and fasteners (Fig. 4). This system has the function of changing the direction of the shafts, to transmit torque and rotation while allowing free movement of the handlebars.

Figure 4. Details of the steering system.

2.1.4 - Front Transmission

The front transmission system consists of the wheel hub, by a pair of bevel spur gears and fasteners (Fig. 5). This system uses the same gear pair used in te rear transmission, but with the reverse gear ratio.

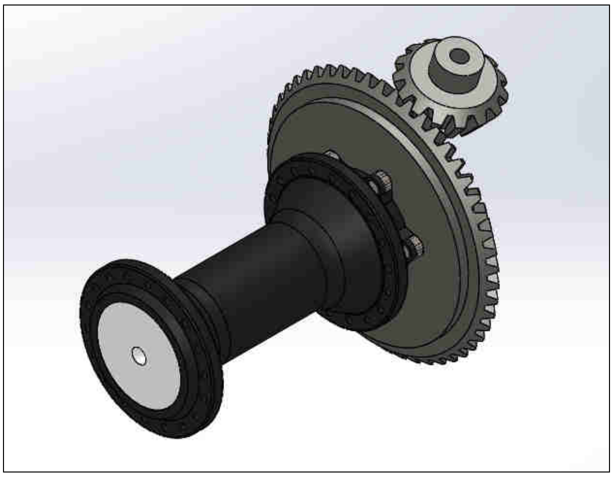

Figure 5. Details of the front transmission system.

3. RESULTS

To calculate the resulting torque on the rear axle, it was considered that at a certain moment the rider is leaning on one foot, exerting a vertical downward force equivalent to their weight. For a cyclist with a mass 90 kg was considered a 90 kgf force applied to the end of the crank arm having a radius of 175 mm. Then, the torque generated by the rider will be 154.5Nm.

For a mountain bike with 27 speeds, 3 toothed wheels in the crank shaft and 9 toothed wheels on the rear axle. The situation which allows greater torque to the rear axle can be obtained from the relationship between the toothed wheel of the crank shaft with a smaller number of teeth and the toothed wheel of the rear axle with larger number of teeth. This relationship is equivalent to a speed ratio of 1.14 (Tab. 1). Therefore the torque on the rear axle will be 176.1 Nm.

Assuming that a mountain bike cyclist maintains a pedaling cadence of about 90 rpm, the rotation on the rear axle, can be given through the gear ratio of the gear selected. For the ratio of 1.14 to rotation of the rear axle is 79 rpm and the resultant power is 1.46 kW. The calculations of the gear ratio, torque, speed and power and were calculated for all gears and shown in Tab. 1.

Table 1. Relationship between the toothed wheels.

March	Larger toothed wheel [Teeth]	Smaller toothed wheel [Teeth]	i	Torque [Nm]	Rotation [rpm]	Power [kW]	Velocity [km/h]
1°	A [22]	I [25]	1.14	176	79	1.46	9.9
2°	A [22]	H [23]	1.05	162	86	1.46	10.7
3°	A [22]	G [21]	0.95	147	94	1.46	11.7
4°	A [22]	F [19]	0.86	133	104	1.46	13.0
5°	A [22]	E [17]	0.77	119	116	1.46	14.5
6°	A [22]	D [15]	0.68	105	132	1.46	16.4
7°	A [22]	C [14]	0.64	98	141	1.46	17.6
8°	A [22]	B [13]	0.59	91	152	1.46	18.9
9°	A [22]	A [12]	0.55	84	165	1.46	20.5
10°	B [32]	I [25]	0.78	121	115	1.46	14.3
11°	B [32]	H [23]	0.72	111	125	1.46	15.6
12°	B [32]	G [21]	0.66	101	137	1.46	17.1
13°	B [32]	F [19]	0.59	92	152	1.46	18.9
14°	B [32]	E [17]	0.53	82	169	1.46	21.1
15°	B [32]	D [15]	0.47	72	192	1.46	23.9
16°	B [32]	C [14]	0.44	68	206	1.46	25.6
17°	B [32]	B [13]	0.41	63	222	1.46	27.6
18°	B [32]	A [12]	0.38	58	240	1.46	29.9
19°	C [44]	I [25]	0.57	88	158	1.46	19.7
20°	C [44]	H [23]	0.52	81	172	1.46	21.4
21°	C [44]	G [21]	0.48	74	189	1.46	23.5
22°	C [44]	F [19]	0.43	67	208	1.46	25.9
23°	C [44]	E [17]	0.39	60	233	1.46	29.0
24°	C [44]	D [15]	0.34	53	264	1.46	32.8
25°	C [44]	C [14]	0.32	49	283	1.46	35.2
26°	C [44]	B [13]	0.30	46	305	1.46	37.9
27°	C [44]	A [12]	0.27	42	330	1.46	41.1

Tab. 1 shows that for the cadence and torque defined initially, the mountain bike reaches a speed of 9.9 km / h in first gear and 41.1 km / h at the twenty-seventh gear, something coherent to the usual standard. The dimensioning of gears was made via the pressure criterion (wear) and flexural strength criterion (Shigley, 2005; Sarkis, 2009). A SAE 8620 steel, hardened and tempered with a yield stress of 200 MPa and a hardness of 60 HRC was used. The results of the sizing of the gears, are arranged in Tab. 2, 3, 4 and 5.

Table 2. Features of the gears of the rear transmission.

Geometric characteristics of the pair of gears		
Description	Pinion [mm]	Gear [mm]
Number of teeth	13	34
Module	2.5	2.5
Pressure Angle	20°	20°
Tooth height	5	5
Angle between shafts	90°	90°
Tooth width	25	25
Pitch diameter	32.5	85

Table 3. Features of the bevel gears of the steering system.

Geometric characteristics of the pair of gears		
Description	Pinion [mm]	Gear [mm]
Number of teeth	13	13
Module	2.25	2.25
Pressure Angle	20°	20°
Tooth height	4.5	4.5
Angle between shafts	90°	90°

Tooth width	23.8	23.8
Pitch diameter	29.25	29.25

Table 4. Features of the gears train of the steering system.

Geometric characteristics of the pair of gears			
Description	1° Gear [mm]	2° Gear [mm]	3° Gear [mm]
Number of teeth	21	21	21
Module	2	2	2
Normal module	2.44	2.44	2.44
Pressure Angle	20°	20°	20°
Tooth height	4.88	4.88	4.88
Helix angle β	35	35	35
Tooth width	11.49	11.49	11.49
Pitch diameter	51.3	51.3	51.3

Table 5. Features of the gears of the front transmission system.

Geometric characteristics of the pair of gears		
Description	Pinion [mm]	Gear [mm]
Number of teeth	13	34
Module	2.5	2.5
Pressure Angle	20°	20°
Tooth height	5	5
Angle between shafts	90°	90°
Tooth width	25	25
Pitch diameter	32.5	85

The pair of rear transmission system (Tab. 2) and the front transmission system (Tab. 5) show the same values, being disregarding mechanical losses that would provoke different data inputs.

4. CONCLUSIONS

Based on the results, it was concluded that the developed solution works as concept, reaching the purpose of transmitting part of the rear wheel drive to front wheel. However, to more accurately quantify the benefits and performance gains, the construction of a prototype system for testing and field evaluations would be required. As for the elements of machines developed after the calculations were found within the expected size for the loads proposed, but considering the major search mass reduction that currently exists between the Mountains bikes manufacturers, a job is necessary to evaluate the project in order to reduce mass.

5. ACKNOWLEDGEMENTS

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