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The Difference in Efficiency Between Final Drive Applications on Motorcycles

Academic Skills - ACHA4005

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Contents

1	Introduction.....	1
2	Final Drive Applications.....	1
2.1	Chain Drive.....	1
2.2	Shaft Drive.....	2
2.3	Belt Drive	2
3	Results and Discussion	3
4	Conclusion.....	4
5	References	5

1 Introduction

This report investigates the difference in efficiency transfer between chain, belt and direct drive methods used on motorcycles to provide transmission energy to the rear wheel, a detailed look into each category and the loss of energy between transmission and the rear wheel will be conducted but also notes on their efficiency regarding; ease of maintenance, cost of maintenance and ease/cost to replace will be made.

2 Final Drive Applications

The final drive transfers power from the engine to the rear wheel (Matthew Coombs, 2002, 4.17).

Motorcycle manufacturing uses three main methods to deliver power from the engine transmission to the rear wheel. A chain-driven final drive is the most popular, followed by a belt drive and finally shaft drive.

2.1 Chain Drive

A chain is made up of six parts that when linked form a length of continuous material that can be attached around a sprocket on the output shaft of the engine transmission to a sprocket located at the rear wheel. (Figure 1)

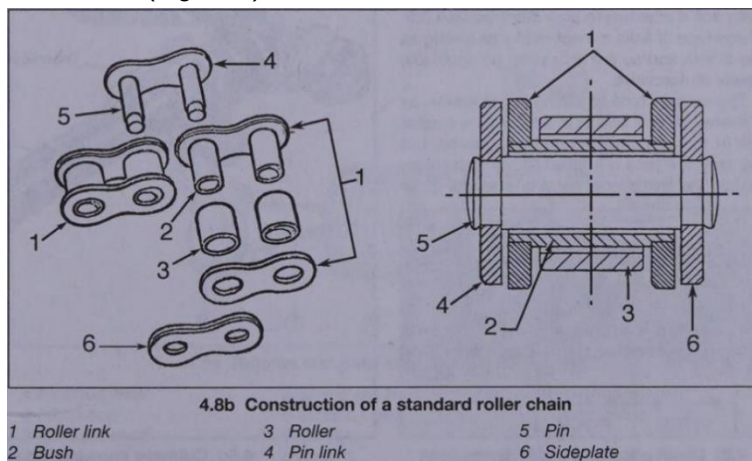


Figure 1: Construction of standard chain roller (Coombs, 2002)

Advances in chain technology have produced O-ring and X-ring systems that assist with lubricating the rollers and bushes and sealing in the lubricating oil. These systems also help keep out dirt and moisture. (Matthew Coombs, 2002, 4.18). Coombs (2002) mentioned that both technologies work the same, but X-ring has the added benefit of improved sealing qualities and frictional drag reduction between the ring and the side plate.

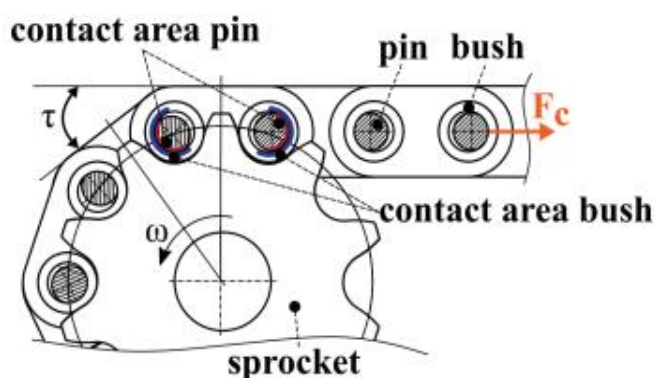


Figure 2: Contact areas inside of a chain joint (Meffert, Oehler, Sauer, 2021)

Other, more recent technological advances have seen coatings applied to the wear points on chains to improve the frictional drag reduction and life span. (Figure 2) ta-c and (Cr,Al)N are used for chain components to gain higher efficiencies due to friction ecoefficiency reduction and improve resistance to wear. (Meffert, Oehler & Sauer, 2021)

Due to their construction and design, new chains are prone to stretching so require adjustment to ensure correct tension parameters and prevent slip or derailing. As the chain is open to the elements cleaning and lubrication are needed to preserve the condition of the assembly parts and allow them to work at their highest efficiency.

Burgess & Lodge (2004) found that the transmission efficiency of a sports motorcycle chain was estimated to be between 96 and 99% at speeds less than 75mp/h. However, the efficiency is reduced to as low as 85% when traveling between 75 and 150mp/h due to inertial tension, this can result in a loss of more than 7hp.

2.2 Shaft Drive

Shaft drive systems provide power using bevelled gears and a connecting rod. They are usually lubricated and cooled using their own supply of oil.

Cocco (2005, p70) states that a shaft drive assembly contains “A transmission shaft, up to the swingarm pivot, longitude to the motorcycle.” Therefore 90° gears must be used to convert the motion from and to its original rotation direction. (Matthew Coombs, 2002, 4.19). (Figure 3)

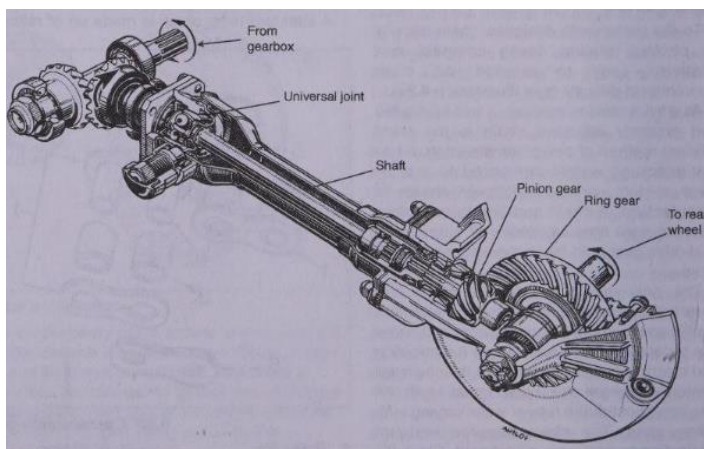


Figure 3: Shaft drive cutaway
(Coombs, 2002)

The need for multiple gears means multiple points of contact and friction are present adding to a loss of efficiency. Cocco (2005, p70) found that the loss of power between bevelled gears is roughly 4 to 5%. This, combined with the cooling and lubricating oil which adds a friction coefficient, and the amount of power it takes to turn the internal components should be considered.

Due to its design, being removed from the elements, and lack of maintenance the shaft drive can be seen as the best final drive application. Although, it does carry a lot of weight and can be expensive to replace if damaged. This added with the greater percentage of power loss should be considered. (Matthew Coombs, 2002, 4.19).

2.3 Belt Drive

Motorcycle belt drives typically use a toothed belt and pulley system that provides power to the rear wheel. (Figure 3) (Koyama & Marshek, 1998, 228)

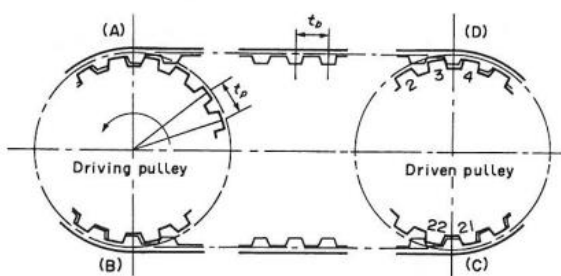


Figure 5: Toothed belt drive system (Koyama & Marshek, 1998)

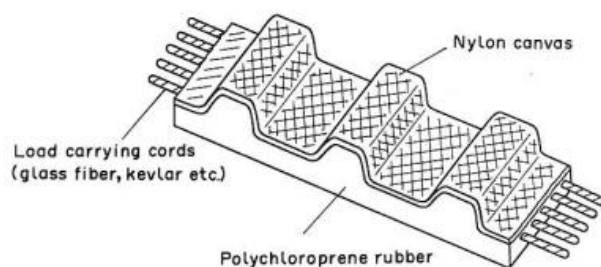


Figure 4: Construction of a toothed belt drive (Koyama & Marshek, 1998)

They are commonly made with a polychloroprene rubber base with a nylon canvas covering the tooth face and structural cords running parallel through them. The nylon canvas is used as a protective layer between the pulley and belt teeth and provides a lower friction coefficient. (Koyama & Marshek, 1988, 228,229)

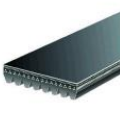
				
type	wedge belt (SP) or V-belt	cogged wedge belt (XP) or cogged V-belt	poly V- or ribbed belt	synchronous or timing belt
efficiency according to manufacturer	up to 97%	up to 97%	up to 96%	up to 98%
measured	up to 97%	up to 98%	up to 97%	up to 99%

Figure 6: Tested efficiency of different belt types (Dereyne, Defreyne, Algoet, Derammelaere, Stockman, 2015)

Due to the construction, a belt drive has some advantages over a chain drive system. Belt drives are lighter and quieter than a chain and have the added advantage of not requiring lubrication or adjustment. (Matthew Coombs, 2002, 4.19).

However, Cocco (2005) mentions that a belt does not have removable links that allow for opening and closure, presenting issues when a replacement is due. As well as the added cost of components due to their extra size. Belt drive pulleys are larger than the sprockets of a chain drive to reduce the amount of bend in the wrapping and unwrapping process, and this also ensures that the drive is spread over as many teeth as possible (Matthew Coombs, 2002, 4.19).

Figure 6 above shows the efficiency rating of belts compared to their manufacturer rating, tested on a custom-built test bench. "The belt pulleys are mounted on dedicated 200 Nm torque sensors. The speed is captured by encoders on both 4p 15kW induction motors of which one is speed controlled (drive side) and the other is torque controlled (load side)." (Dereyne, Defreyne, Algoet, Derammelaere, Stockman, 2015)

3 Results and Discussion

Taking the information above, it is clear that chain drive has had the most research and development. Chain drive is popular, no doubt, due to its ease of maintenance and cost-effectiveness.

However, comparing the efficiency between chain and belt drive a belt has better power transfer capabilities. The belt drive is a great replacement for a chain drive, it requires less general maintenance than a chain as the belt does not stretch so no adjustments are required, however, due to the design of the belt fitting a replacement can prove technical and time-consuming, as well as the added costs of other components in the drive, that due to size will no doubt cost more than a chain drive replacement.

4 Conclusion

The above results declare that the belt drive is the most efficient in terms of power transfer, however, it is good to consider the ease and cost of maintenance under the term “efficiency”.

Each application has its unique characteristics, pros, and cons. Applied to the correct motorcycle the positives will no doubt outweigh the negatives.

It is no surprise that chain drive has received the most research and development, it is the cheapest and most time-efficient way to provide power to the rear wheel. Future advances may include a pre-stretched chain that removes the need for chain adjustment intervals as well as more advanced lubrication technology that further increases the time between maintenance windows.

In future testing, it would be useful to conduct the same tests on all three applications, possibly in way of bench testing that includes varying speeds, loads, temperatures, and humidity as well as including logs of time taken on maintenance.

5 References

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