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Motorcycle Geometry Analysis

Motorcycle Engineering (ACHA4003)

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1. Introduction

The shape of a motorcycle has a great impact on the performance and handling characteristics of the bike. Because of this, it is important that the geometry of a motorcycle is carefully considered when designing. As well as this, certain features can be made to be adjustable which will allow geometries to be slightly adjustable to track or road conditions. Geometry adjustments mainly affect the handling characteristics of the motorcycle.

Another factor to be considered is the gear ratios of a motorcycle. The optimum gear ratios are always a balance between achieving maximum top speed from the bike without sacrificing on acceleration. Correctly tuned gear ratios can make a massive difference on track, shaving off large amount of time. On the street, adjusting gear ratios can allow for greater efficiency from an engine, saving on fuel.

A third important factor to be considered is the final drive ratio of the bike. This is calculated from the difference in teeth between the front and rear sprockets on the bike. A small change of adding or subtracting teeth from sprockets can make a massive difference to the performance of the motorcycle.

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2. Motorcycle Geometry

Motorcycle Geometry is typically broken up into two sections. The first section is front end geometry which consists of Trail, Rake and Offset. The rear end geometry consists of the anti-squat geometry of the bike, such as the angle of the swing arm, The dimensions of the chain and the rear suspension design.

2.1 Front Geometry

The trail of a bike is defined by the distance between the contact patch of the front tyre and the front fork, with a line from the fork extended down to the ground. This distance should be on a horizontal plane. Trail is typically measured in millimetres for motorcycles.^{2.1} Trail is very important for motorcyclists as it affects both stability and the turn in sensitivity of the motorcycle. A higher trail will make the motorcycle feel more stable and reduce speed wobble. This is desirable for street motorcycles, especially cruisers which will make it more comfortable for riders on long distance journeys. This comes at the expense of turn in response, which is more important for race bikes. Because of this, track bikes will typically have a much lower trail to allow for faster corners.^{2.2}

The rake of a motorcycle is defined as the angle between the vertical axis and the steering head of the frame, measured in degrees. This angle is the same as the angle that defines the trail of the bike, and these two geometries are closely related, though not exactly the same as rake is measured as an angle, whereas trail is a measure of distance.^{2.3}

2.2 Rear Geometry

The final Important element of front geometry is the offset. This is measured between the axis at the centre of the steering hub and the centre of the steering tubes. Adjustments to the offset can be made with replacement yokes, which in turn can be used to adjust the trail and rake of the bike.^{2.4}

The first part of rear geometry is the swing arm pivot. When the swing arm slopes up from the rear, The driving force from the chain pushes against the force of rear of the bike moving downwards due to the weight transfer under acceleration. This mechanism is known as anti-squat.^{2.5}

Another important part of the rear geometry of the bike is the characteristics of the chain. There are many factors to consider when designing the chain for a bike, including the number of links, the size of the links, as well as the overall length of the chain.^{2.6}

2.3 Centre of Gravity

The centre of gravity of a motorcycle is another important element to consider when designing. This is because the centre of gravity can have a dramatic effect on the stability and handling characteristics of a motorcycle. The centre of gravity can be calculated both on the vertical axis as well as on the horizontal axis. To calculate the centre of gravity of a motorcycle, it must be weighed on both of the wheels independently. This can then be used to calculate the centre of gravity of the motorcycle. This can then be expressed as a decimal between 0 and 1, with 0.5 showing a perfectly centred balance. This can also be calculated with a rider to show the centre of gravity when in use.^{2.7}

3. Motorcycle Gearing

Another Important factor to consider when designing a motorcycle is the gearing. This has a big impact on the performance of the bike as it directly controls how power is transmitted from the engine to the wheels. Because of this, gearbox design should be considered a priority. The final drive is also a priority as this is responsible for transferring the power from the gearbox to the wheels. The final drive is made up of the sprockets and chain. Changing the size of the front sprocket compared to the rear sprocket can also dramatically change the performance characteristics of a bike.

Shorter gear ratios are desirable for race motorcycles as shorter ratios will allow the bike to accelerate faster and allow the bike to stay in the higher rev range of the engine which will also allow more power to be transmitted to the wheels. This however, comes at the expense of higher fuel usage but this is less of an issue for track bikes as during a regular race they will typically be running for less than 45 minutes, meaning they should be able to finish a race without having to refuel. This may however be an issue for longer endurance races. Shorter gear ratios also have the issue of placing more wear on the engine and internal components, but as race bikes are often rebuilt between races this is less of an issue than with street bikes.

Longer ratios can be used for street bikes, especially cruisers and tourers as achieving maximum power is less of a priority. Longer gear ratios will allow these bikes to use less fuel, meaning they will have a far superior range for the same amount of fuel. This is also important for small commuter bikes as it will also save the rider money on fuel. Another advantage of long gear ratios is reduced stress on the engine as the internal parts will be moving at a slower speed, allowing them to have a longer service life.

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