New design approach for leaf-springs in motorcycles

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Abstract:

A leaf spring is a very simple type of mechanical spring which is commonly used for heavy duty suspension systems. In single-track vehicles, such as motorcycles or bicycles, the coil and air spring are most widespread as well as current state of the art. However, the application of a leaf spring is nothing new on these types of vehicles. Various design approaches can be admired in museums. A century ago, it was even more common than the coil spring, but history shows us that this spring system has gradually been replaced due to its inherent disadvantages. In this document, we want to introduce an alternative leaf spring design and the associated benefits. One that at the core is old and simple in form but utilizes new approaches and technologies to meet the demands of modern motorcycle and improve riding behavior.

Usually, a leaf spring consists of one or more thin narrow plates that are located between the frame and axle. These are normally thicker in the middle and taper out towards the end to act as a three-point bending beam. The key point of our concept is the elimination of one connection point. Therefore, only two connection points are utilized and the spring with associated attachments is pivoted to the main frame at the upper end and to the swingarm at the lower end.

Figure 1. Positioning of the leaf spring in the motocross bike
At first glance this seems like a small step, but it fundamentally changes how the leaf spring is loaded and results in several advantages. In the following paragraphs we would like to explain a few of them in detail. The information is always presented relative to the currently standard coil spring and at the beginning of each topic the requirements of the modern offroad motorcycles are explained.

The first advantage is the spring material. The current coil spring is generally made from steel or titanium for motorsport applications. In contrast the leaf spring can be made from composite materials. For the sake of completeness, it must be mentioned that it is possible to have a composite coil spring, but they are very complex to produce, expensive and bigger in size. The leaf spring is comparatively easy to manufacture since it only consists of unidirectional layers. The composite material and its associated properties (high specific strength and high specific modulus) open the door for a lightweight product with small dimensions. The material properties along with the reduced unsprung mass improve comfort and NVH.

The second advantage is the spring characteristics. Demonstrated as the wheel force vs. wheel travel. A highly progressive spring characteristic is used to ensure good riding comfort at standard ride-height and sufficient suspension travel reserve in case of big suspension inputs. For motocross bikes this characteristic is typically generated by a special linkage. For the leaf spring concept, the linkage is not necessary because the progressive characteristic comes from the spring itself. Figure 2 shows the elastic deformation of the spring assembly at a fully compressed suspension condition. The rotation of the upper attachment point is essential for the increase in spring stiffness with increasing suspension travel. The amount of spring progression that is generated always depends on the spring geometry. For example, the spring design in Figure 2 more than doubles the spring rate during a full stroke (without any additional linkage).

![Figure 2. Unloaded spring condition (semi-transparent) and fully loaded condition](image_url)

Although there are other interesting aspects to this spring concept, the last point is intended to explain the packaging advantages in terms of space requirements. The green dashed circle in Figure 1 shows a particular packaging hotspot on a modern motocross motorcycle. For the rider’s ergonomics, it is particularly important that the bike is relatively slim in the area of the legs/footrests. If it is too broad, then the rider must spread his legs very wide while standing on the bike and this leads to an uncomfortable posture. At the same time packaging space must be available in that area for components such as, the air intake for the combustion engine, exhaust pipe and shock absorber. These two requirements normally contradict each other. Due to the fact that the leaf spring is placed in a different position we can improve that hotspot and generate free space which can then be used to optimize other components. While not explicitly related to the suspension, the leaf spring is a first step to improve different vehicle attributes. For example, engine performance because of the possibility to package a bigger air box.

References