The XB motorcycle platform is loaded with innovative features and concepts, and one of the key features that makes an XB unique is the belt drive system. What's so special about the XB's belt drive system? To the rider it's two things – constant tension that eliminates all driveline slop, and adjustment-free ownership. To an engineer, it's much more complex.

So, what's up with the idler pulley?

by Dane Hoechst,
Lead Design Engineer

Motorcycle secondary chain drives and belt drive systems have an inherent problem. The engine output sprocket is connected to the engine and stays in one location, while the rear wheel sprocket rides up and down with the rear wheel as the swingarm travels through the range of suspension travel. This would not be an issue if it wasn't for the fact that the swingarm pivots around a different axis than what the engine output sprocket rotates on. This causes the center-to-center distance between the two drive pulleys to constantly change.

To combat this inherent problem on most motorcycles, the rear suspension layout is designed to minimize the amount that this distance changes. One of the ways to do this is to make the swingarm as long as possible so the angle of the swingarm does not need to change very much in order to achieve the desired rear wheel travel. Another way to do this is to design the rear suspension geometry in a way that the swingarm spends time above and below "center."

Center is defined by the point at which the axis of the rear wheel, the axis of the swingarm pivot, and the axis of the engine output sprocket all lie in a straight line. On typical motorcycle rear suspension geometries, this is the point at which the belt (or chain) path is the longest. As the rear wheel moves above and below this line during suspension travel, the center-to-center distance gets shorter.

Designing a rear suspension geometry that results in the desired performance characteristics is an art. One of the main characteristics that is designed into the XB geometry is "anti-squat." Anti-squat is a design concept that extends the rear suspension during acceleration, therefore pushing the tire into the ground for maximum traction. It also keeps the chassis geometry more constant, as it fights back against the acceleration forces that normally compress the rear suspension and extend the front, causing a bike accelerating out of a corner to "motorboat" and run wide out of the corner. In order to tune the vehicle to have the desired amount of anti-squat, the swingarm pivot axis and the angle between the swingarm and the ground is varied. In the case of the XB, we desired a large amount of anti-squat. This resulted in a rear suspension geometry that caused the secondary drive system to spend its entire life below center.

A drive system in which the entire swept path of the swingarm is below "center" creates a very large amount of center-to-center distance change. Under hard acceleration, the belt path is at its shortest point during the time at which the torque load is the highest. With the combined effect of these issues, the early prototype XB's secondary drive system was so loose when the rear shock was fully extended that it would cause belts and chains to skip over sprocket teeth under hard acceleration. Typical spring mounted idlers were jerked around during hard shifts and downshifts; adding enough spring rate to overcome this would cause undue forces to be pushed into the belt.

This was a very big hurdle to overcome. We could have modified the rear suspension geometry to avoid this condition, but that would be at the expense of our desired anti-squat characteristics. Because Buell prides itself in making the best handling motorcycles on the market, we decided not to compromise our desired anti-squat characteristics and set off to find a way to make the drive system function in spite of the conditions imposed upon it.

We needed to make the belt path act like it's at its tight spot while the rear shock was in its fully extended state. To accomplish this, we theorized that we could place an idler pulley under the lower span of the drive belt in order to counteract the reduction in belt path length, as the rear shock moved from its fully compressed state to its fully extended state. The concept was to place an idler of the right diameter in just the right location along the lower span of the belt that just barely contacted the belt when the rear shock was fully compressed. As the rear shock extended and the swingarm rotated downward, the idler pulley needed to increase the belt path length at the same rate at which the belt path length decreased when the idler was not there. The end effect would be to minimize the overall change in belt path length throughout the range of suspension travel.

We started the investigation by pure trial and error, placing the idler in different locations in three dimensional CAD space. This allowed us to measure the path length around the drive system at various swingarm angles to see if we were on the right track. This exercise quickly revealed that our concept was successful in reducing the overall change in belt path length over the range of suspension travel. However, we realized that the location of the idler pulley was extremely sensitive. If the idler was placed in the wrong location, its effect was too extreme and caused the belt path to get longer.

In order to optimize the location of the idler pulley for various drive systems that were under development, we needed to find a way to mathematically tell us where the best location was. We decided that if we could derive an equation that described the belt path length over the range of suspension travel, we could graph it against the idler pulley location to help us quickly find the proper location. An equation was derived to solve for belt path length, taking into account rear suspension geometry, swingarm length, belt length, idler pulley diameter, sprocket diameters, idler pulley location, and suspension position.

The resultant equation was too complex for our standard spreadsheet program to solve. To get past this hurdle we purchased an advanced mathematics software package. This package could not only solve the equation, but it had the capability of graphing it in three dimensions. The 3D graph that we set up showed belt path length vs. suspension position and idler pulley location on its three axes. The other variables in the equation were known with the exception of the exact swingarm length. This dimension was used to fine-tune the belt path length to get it to fall on an incremental belt length. (Belts have a particular pitch length, or distance between teeth, so we could only add or subtract one tooth at a time.)

You will notice in the graphs that the map it draws out looks like a curled and twisted surface. Because the range of suspension travel was already defined, we chose to place suspension position on the z-axis and align the graph so that it was pointed directly into the page. This way, we were able to evaluate the effect of the two variables that we could change with its resultant range of path length due to suspension travel. When the z-axis is aligned, the graph shows an inflection point. This is the location where we want to put the idler because the resultant belt path length variance is smallest at this point.

Using this method to place the idler pulley, we were able to take a drive system that originally had about .375" difference in belt path length from longest to shortest points down to less than .010". This resolved the belt and chain skipping issue and allowed us to keep our suspension geometry right where we wanted it. In addition, the virtually constant belt path length resulted in a significant reduction in secondary drive lash and better connected the throttle grip to the rear wheel.

Result? We solved what had long been seen as an insurmountable problem in design and achieved the optimum result of superior vehicle performance while at the same time providing a very low maintenance system.

Typical Rear Suspension Geometry

XB Rear Suspension Geometry