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SELF-BALANCING MOTORCYCLES: THE TECHNOLOGY AND CHALLENGES

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Self-balancing Motorcycles: The Technology and Challenges

Self-balancing motorcycles are heralded as the future of transportation. They feature integrated technology that prevents riders from painfully toppling over on scorching asphalt. Motorcycles can weigh between 300 and 500 pounds, making them challenging for novices, women, or elderly individuals to lift. The innovation of self-balancing motorcycles prioritizes rider safety by eliminating the risk of tipping over. These advanced motorcycles prove invaluable for riders lacking experience, particularly when stopping at red lights and maneuvering at low speeds in cities. By removing the constraints of balance and skill required for conventional motorcycles, these specially designed bikes become accessible to people of all ages, except for unlicensed children.

For instance, navigating through narrow gaps between closely parked cars demands precise control to avoid mishaps. With cutting-edge technology, self-balancing motorcycles are equipped with many mechanisms and techniques that ensure unparalleled stability. The motorcycle companies Honda, Harley Davidson, BMW, and Yamaha have been at the forefront of developing self-balancing motorcycles. The advantage of multiple companies pursuing the same objective is the diversity of technologies they bring to the table.

Harley-Davidson employs a gyroscope-driven design, while Honda integrates a front-fork mechanism. Yamaha harnesses an inverted pendulum and gravity manipulation technology, and BMW incorporates a trio of cargo technology boxes. This effort among leading manufacturers showcases the drive for innovation and promises a range of advancements in self-balancing motorcycle technology.

Harley Davidson - The Gyroscope

A gyroscope works by constantly rotating to maintain balance through the orientation of its rotation. The exact science is applied to bicycles, which is how they stay upright. This is known as hyperphysics. As the rider leans to the left, torque is created, causing counterclockwise precession of the wheel, which turns left.

The gyroscope in a self-balancing motorcycle has two functions. The first function is to detect changes in the bike's angle, tilt, and lean. Next, sending an equal force to the opposite angle or side keeps the motorcycle upright. For this technology to function correctly, it is typically mounted at the bike's center of gravity, keeping it balanced from the middle. Once the motorcycle tips over to one side, the gyroscope sends signals to the main frame of the vehicle, where it then adjusts electrical motors to correct the balance, keeping it upright and stable without the rider struggling.

Ben Purvis (2020) of *Cycle World* magazine explains the basics of gyroscopes and the technology, "The gyroscope is made up of a heavy flywheel, spun to between 10,000 and 20,000 rpm by an electric motor mounted in a gimbal that, during normal riding, allows it to move in both the roll and pitch axis freely. That means it doesn't influence the bike's behavior apart from some additional weight." It is noted that these gyroscopes come into play at low speeds, ranging from below three mph, as a balance aid. When the motorcycle travels at such speeds, a clutch opens, locking the axis to a lever connected to a computer. This computer controls an actuator that converts energy into mechanical force; this helps tilt the mass from side to side, allowing the motorcycle to achieve balance. Once it reaches faster speeds, the machine will automatically shut off, allowing for the rider's control. For novice riders who want to experience Harley-Davidson motorcycles but have relatively few years of experience, these kinds of motorcycles are highly beneficial, as well as for older riders who lack the strength to handle a regular bike. The gyroscopes on Harley Davidson motorcycles are cleverly integrated into the upper section of the cycle, as opposed to having a conspicuous protrusion in a haphazard location. “The patent drawings show the gyro unit is stored in the top box and includes another heavy flywheel and an electric motor which would make the bike even heavier” (Hinchliffe, 2020). This design choice maintains a sleet aesthetic and opens the potential for seamless transferability to different motorcycle models and makes.

Honda - Front Fork

According to Honda, while gyroscopes effectively aid in balancing motorcycles, they tend to contribute excessive bulk and weight., so the company developed its “riding assist” technology that does not use large gyroscopes, which will not “add a lot of weight and limit the bike's ability to maneuver,” according to the company (Matsumoto, 2017). To this end, Honda introduced the front fork, a novel technology in self-balancing motorcycles, creating one of the pioneering autonomous and self-balancing motorcycles. Their achievement involves melding self-balancing capabilities with artificial intelligence, resulting in a motorcycle that can maintain impeccable balance.

Honda's balancing mechanism operation is similar to Harley Davidson's gyroscope-equipped counterpart.

When a motorcycle equipped with Honda’s riding assist technology moves at four mph or less, a modification in the fork angle is initiated, causing the front wheel to move forward. This adjustment forms the core of Honda's self-balancing system. Unlike gyroscope-based motorcycles, where abrupt angle changes are countered with opposing angles, Honda's approach involves gradual fine-tuning to uphold the bike's overall balance. This technology empowers riders to stand upright on their motorcycles without any risk of tipping over. This feature is valuable for beginners and experienced riders grappling with the intricacies of maneuvering through traffic or navigating stoplights, where delicate adjustments are crucial. In such scenarios, the motorcycle is susceptible to toppling over. Incorporating a gyroscope, while effective for balance, would dramatically alter the riding experience by introducing substantial weight and unwarranted movements due to the constant spinning motion of the gyroscopic device.

In 2022, Honda introduced enhancements to their rider-assist motorcycle. They transitioned from employing the front fork to a swing arm with a gyro sensor. This sophisticated technology orchestrates the lateral movement of the rear wheel, effectively sustaining the motorcycle's equilibrium. The rhythmic back-and-forth motion of the rear wheel, facilitated by this technology, enables the bike to maintain an upright position without requiring any rider intervention.

Yamaha - Pendulum

Yamaha's ASMAS (Advanced Motorcycle Stability Assist System) follows a path similar to Honda’s rider assist. Yamaha has integrated two actuators – similar to those found in gyroscopes – but there are two. One is dedicated to the front wheel, while the second focuses on the handlebars. This setup allows manipulation of the front wheel and steering, leading to even better stability. This technology has already been incorporated into one of their models, the YZF-R25. "From here on, we'll be working to downscale the sizes of the various components, as we want to develop it into a platform not just for motorcycles but one that is also adaptable to a wide range of other personal mobility applications, such as bicycles," said project leader Akitoshi Suzuki (Prestidge, 2023).

Yamaha's unique concept is based on physics, distinct from gyroscopes and front forks. The company has introduced an inverted pendulum. This concept is also used in rocket launches to enhance vertical stability. Imagine the motorcycle as the pendulum – if its center of mass is positioned above its pivot point, it becomes inherently unstable and prone to tipping over. To counteract this, an external force is required. This force monitors the angle and horizontally adjusts the point under the center of mass whenever tipping starts, effectively stabilizing the motorcycle.

Like Honda, Yamaha has experimented with a prototype motorcycle called Active Mass Center Control System (AMCES). However, this system involves a complete redesign of the motorcycle. Yamaha placed the battery under the frame, allowing the bike to stand upright without a kickstand. The bike could then respond directly to the rider's weight and riding style, maintaining an optimal balance based on the rider's preferences.

In 2017, Yamaha introduced the Motorid, a bike that actively shifts its center of gravity – a concept often called gravity manipulation. As their next step, Yamaha plans to downsize the actuators in their latest models, aligning with the demands and desires of their customers.

BMW – Cargo

The German company BMW has developed the R1200 GS, a fully autonomous motorcycle to enhance rider safety and comfort. This innovative prototype can operate entirely on its own, maintaining balance without any rider input. Despite resembling a typical motorcycle, the R-1200 GS is equipped with three cargo compartments filled with various technology, including computers, sensors, and a GPS. These components seamlessly manage the throttle, brakes, clutch, and steering, delivering a genuine sense of autonomous self-balancing (Blain, 2018).

This advancement introduces minimal alterations to the conventional motorcycle design, with the only noticeable change being the addition of the three cargo containers at the rear. BMW's primary objective is to ensure rider safety while preserving the essence of a traditional motorcycle experience. This groundbreaking prototype serves as a valuable tool for novice riders, instilling confidence by reducing the occurrence of tips and falls. Moreover, the motorcycle aids in enhancing rider awareness by assisting in balance and braking, fostering continuous improvement in riding skills.

It is worth noting that the fundamental distinction between cars and motorcycles lies in their braking mechanisms. When a car's brake pedal is pressed, it stops completely, whereas abrupt braking on a motorcycle can lead to dangerous situations. BMW's autonomous motorcycle addresses this critical issue by employing micro-adjustments and sensors to alert the rider, thereby preventing potentially life-threatening incidents.

BMW's motivation behind this project is not merely to create a riderless motorcycle for novelty. Rather, they view this as a test platform to gain deeper insights into motorcycle riding dynamics, "This prototype helps us to expand our knowledge about the vehicle's dynamics so that we can classify the rider's behavior and determine if a future situation will become dangerous or not," says BMW team member Stefan Hans (Blain, 2018).

With minimal changes to the motorcycle, BMW has added an antenna and software pack with no changes to the design. This design is for disguise, allowing the rider to avoid others detecting balancing-assist motorcycle.

Challenges

Motorcycle companies are reluctant to make self-balancing motorcycles available to the public. They are not putting self-balancing motorcycles into mass production. These motorcycles are unlikely to become a widespread mode of transportation, primarily due to factors such as high costs and limited technology. The expense of self-balancing motorcycles far exceeds that of their conventional counterpart because of the gyroscopes, computers, sensors, and accelerometers, among other technologies. While a regular motorcycle might range from $4,000 to $20,000, these prototypes increase the cost by approximately 20%. This creates a dilemma for inexperienced and older riders as these models are marketed towards them, yet their steep pricing hinders acquisition. An illustration of this is Harley Davidson, which offers one of the most expensive bikes in the market. By incorporating gyroscopes into the system, the price of the bike surges to around $32,000.

Another drawback of self-balancing motorcycles is their limited customization potential, which many riders want. Unfortunately, creative possibilities in this area are limited by unchangeable elements in the core design of the self-balancing motorcycle. Additionally, the gyroscope model is closely tied to its technological components, making it impractical to extract or modify this technology effectively.

Electric motorcycles also have a great potential for technological malfunctions. Self-balancing vehicles composed of electric parts are susceptible to occasional glitches and faults. However, the critical distinction between cars and motorcycles lies in the outcome of such malfunctions. In the case of motorcycles, the stakes are higher as a malfunction could result in the loss of self-balancing capability, thereby endangering the rider. As an illustration, a potential occurrence could involve the gyroscope mechanism experiencing obstruction due to inadequate lubrication, resulting from insufficient grease or oil application to facilitate the smooth rotation of its metal components. Additionally, operational issues may arise from the detachment of wires connecting to the mainframe, further accentuating the potential challenges associated with the system's functionality. As companies employ new technology, there will be few mechanics or technicians to fix them much less materials and tools.

In addition to malfunctions, self-balancing motorcycles carry a considerably higher weight than the typical motorcycle. While an average motorcycle falls within the range of 300 to 500 pounds, the self-balancing motorcycle weighs about 600 pounds or more, especially the gyroscopic model. This increased weight poses a significant problem, even for riders with greater strength.

The self-balancing motorcycle's expected weight undermines the practicality for an intended consumer, the older rider, as its weight is hard to lift after it topples over.

While self-balancing motorcycles offer technological promise, there may be limited public availability due to their higher price, constrained customization options, concerns over potential malfunctions affecting rider safety, excess weight, and the higher costs from advanced technology and possible maintenance needs (Tech Seldom, 2023).

Marketing - Addressing the Challenges

To promote self-balancing motorcycles, companies have altered the design to accommodate the new advanced mechanisms and create more streamlined and inconspicuous models. This approach aims to enhance the appeal of self-balancing motorcycles while maintaining their efficiency compared to larger models. The sleeker, less bulky designs are more likely to attract potential customers, seamlessly blending in with conventional motorcycles. This strategy alleviates potential embarrassment customers might feel when purchasing an assisted bike.

The technology needed to manufacture self-balancing motorcycles is costly and impractical for mass production to meet the general public's demands. Honda, however, seeks to create a motorcycle that is safe enough for older people - a growing demographic - to ride independently. Honda is eyeing Japan's 70-80-year-olds, who will outnumber 20-30-year-olds two to one by 2050.

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