

Corner Adapting Motorcycle Headlight

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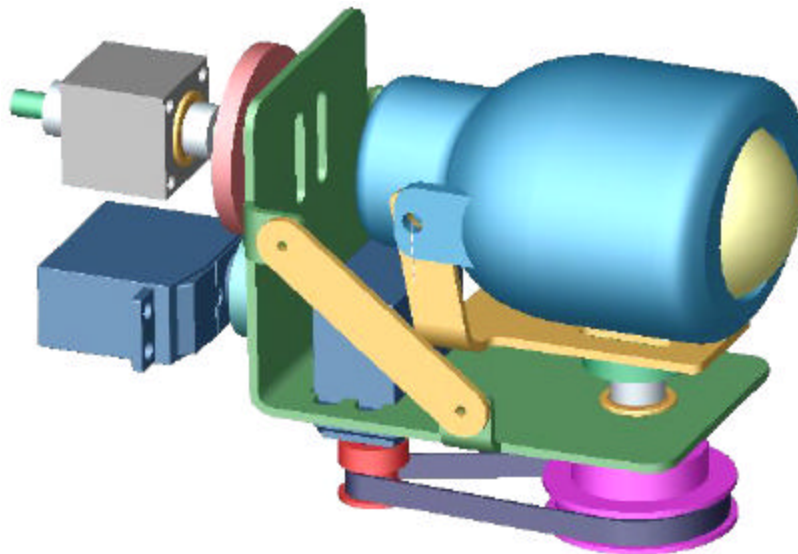
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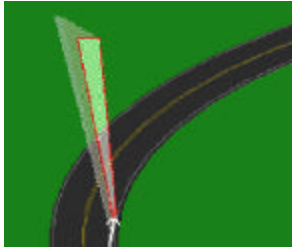
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Abstract

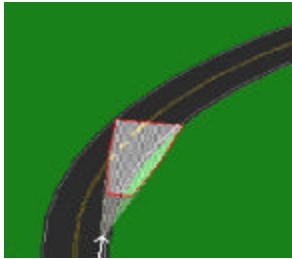
The purpose of this project is to improve motorcycle lighting in corners. Given that motorcycles need to lean or *bank* to turn, the headlight aim becomes obscured and inadequate around curves. This lighting phenomenon can present a safety hazard to riders at night. Although this problem has been present since headlights were first put on motorcycles, it is now prudent to accept the challenge of correcting this problem thanks to the recent advances in sensor and microprocessor design. The solution was to design a headlight control system that sensed the motorcycle's dynamic behavior, predicted the current situation on a roadway, and manipulated the aim of the headlight to best illuminate the roadway. The system senses the bank angle and speed of a motorcycle, and then uses that data to manipulate a small projector beam headlight. The result of the project is a light that reacts to the banking of a motorcycle and corrects the beam aim quickly and accurately along two axes. In this project a working prototype was constructed. This prototype will be used to demonstrate and prove the concept with the intention of marketing the technology to motorcycle manufacturers.



Need for the Corner Adapting Headlight



250ft radius @ 55mph,
 $\beta = 39^\circ$, Existing
headlights



Corrected headlight

Motorcycle headlights are designed to conform to safety standards when the motorcycle is traveling straight and upright. When the motorcycle is cornering and banked, the light is no longer pointing where it is needed. The headlight shines at the same angle the motorcycle is banked at – sometimes approaching 50° from horizon. Due to the geometry of the headlight beam-pattern, the light actually appears to move away from the intended path. This is a serious problem and can limit a rider's view at night causing a hazardous situation. This is important because 58% of all single-vehicle motorcycle accidents resulting in a fatality in the United States during 1999 occurred at night. It is also interesting to note that 50% of all accidents (same conditions) resulting in a fatality occurred while the rider was negotiating a curve. This trend in motorcycle crash statistics illustrates the need to improve a riders view at night.

NOTE: All Statistics from NHTSA, report # DOT HS 809 360, Oct. 2001

Design Objectives and Requirements



Example of the
extreme lean angles
that motorcycles
undergo.

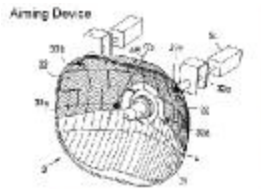
The goal of the project was to increase a rider's safety while cornering a motorcycle at night. To meet this goal the objective was to design and construct a corner adapting motorcycle headlight that corrects for the lean angle of the motorcycle and aims the headlight to the optimal location on the road. The final design is used as proof of concept to demonstrate the technology feasibility. The headlight and control system were incorporated into a demo-stand that allows for bench testing and presentation. There were several design requirements that were considered during the design process.

- Utilize an off-the-shelf headlight that meets SAE specifications.
- Accurately monitor the dynamic conditions of the motorcycle (speed & bank angle).
- Keep the cost of the prototype and demo-stand under \$1,000 budget*.
- The headlight unit must be able to withstand the environment of a motorcycle, i.e. temperature, moisture, vibration, and shock
- Headlight must be small enough to occupy the same space as current headlights in order not to interfere with styling/aesthetics.
- Minimize weight of components in order not to exceed maximum torque specifications of servos.

*Actual cost of
materials for prototype
was \$410.00

This project represents a combined effort of a Mechanical Industrial and Manufacturing Engineering (MIME) capstone team and an Electrical Computer Engineering (ECE) capstone team. The mechanical team was responsible for dynamic modeling of a motorcycle, design of the headlight aiming device, and building of the demo-stand. The electrical team was responsible for the design and building of the control system for the headlight. The development of the algorithm and integrating of the mechanics with the control system were joint tasks.

Design Concepts Considered



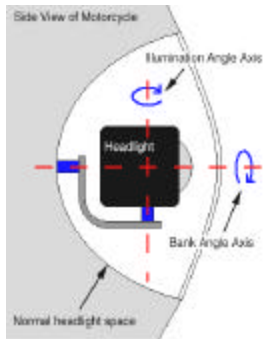
Flexible reflector manipulated by linear actuators. Image from Patent # 5599085

There were two other design concepts considered before deciding on the independent two-axis design we chose. One design employed a regular reflector headlight that incorporated flexible reflector material to be manipulated by linear actuators. This concept, although slightly simpler to control, would involve complex optics problems requiring expensive computer modeling software. The design was also a compromise in that it could only control one axis of light rotation, which is not well suited for motorcycle banking.

A second concept involved manipulating a projector beam using a single servomotor that would correct for the banking angle. The back of the light would be attached to a shaft, which would ride along a curved cam as it rotates. This concept required designing a cam shaped for an average corner radius given a lean angle. Although the concept is better than correcting for just the banking angle because it also points the beam into the corner, it represents a compromise in beam control and is optimal for only one specific riding situation. The two-axis design can accurately compensate for every speed and lean angle combination encountered.

A two-axis system was selected. A primary axis for bank angle (β) compensation and a second axis for illumination angle (α).

Recommended Design Concept



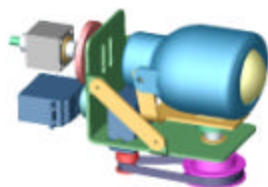
Side view of a motorcycle headlight and the two axes of rotation, banking and illumination.

$$R = \frac{v^2}{g \tan \beta}$$

Equation 1
 R = corner radius
 v = velocity
 β = bank angle
 g = gravity

$$\alpha = \sin^{-1} \frac{L}{2R}$$

Equation 2
 α = illumination angle
 L = illumination distance



Final prototype design of headlight aiming device

The final design for the corner adapting motorcycle headlight (CAM-H) is comprised of three main components. The first is a group of sensors to detect the dynamic conditions of the motorcycle. The second is a control system that reads from the sensors and through calculations outputs to the third component, the headlight aiming device, the correct positioning of the light.

To accomplish the goal of increasing the safety of riding a motorcycle at night, the headlight must be orientated correctly and aimed at the proper location. To achieve this, correction of the headlight's aim on two separate axes is needed.

PHYSICS - The first correction is rotating the headlight so the beam is level to the road. The second is rotating the headlight to the left or right to illuminate the path that the bike will follow instead of pointing straight ahead. To anticipate the path the bike will follow (the curvature of the road radius) the dynamic conditions of the motorcycle must be identified. The radius of the turn can be calculated knowing the lean angle and speed of the motorcycle, using equation 1. After determining the radius of the roadway, the correction to the left or right is given by equation 2.

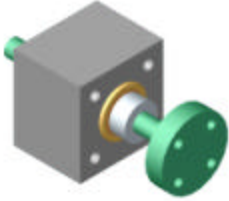
DEVICES - To measure the lean angle of the motorcycle a piezo-electric gyroscope in conjunction with an inclinometer was used. The speed was measured with a hall-effect sensor.

INTEGRATION - The control system consists of the microprocessor and its associated electronics. It detects the inputs from the sensors, (hall-affect, gyro, & inclinometer) computes the optimal headlight aim-point, and conveys the corresponding output signal to the servos.

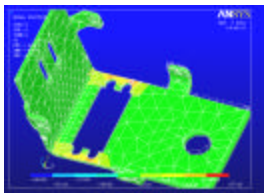
The prototype CAM-H was inserted into a 1999 Suzuki GSX-R 600 headlight assembly. The headlight assembly has two lights, one is the standard reflector beam headlight and the other is the final design for the CAM-H. The CAM-H uses a projection beam headlight. These headlights are compact but still provide the same amount of light as traditional reflector beam lights. The light is held by an aluminum bracket, which is mounted on the illumination angle shaft. A bearing is pressed into the cradle, which supports the illumination shaft and allows it to rotate to the left and right. The cradle is an L-shaped aluminum bracket that is connected to the bank angle shaft. The bank angle



Cradle, bearing, and illumination shaft.



Bearing block and bank angle shaft.



FEA stress analysis

shaft is supported by two bearings, which are pressed into a bearing block. It allows the headlight to rotate, compensating for the bank angle. Servos rotate both shafts. For rotation of the illumination shaft, the servo is mounted in the cradle and connected to the illumination shaft via two pulleys and a drive belt. The pulleys have a reduction ratio of 3.33. This reduction increases the torque and resolution that the servo can apply. Two gears with a reduction of 1.75 drive the bank angle shaft. A back-plate is used to mount the aiming device inside of the GSX-R's headlight-enclosure assembly. The servo that actuates the bank angle shaft is also mounted to the back-plate.

Finite element analysis (FEA) of the CAM-H components was conducted during the design process to insure that the shafts and brackets could withstand the harsh stresses caused by shock and vibration. Simplified models were used in place of more intricate components where the complicated geometry made FEA analysis impractical.

With the gear ratios chosen, the CAM-H is able to correct for motorcycle banking of just over 50° in both directions. The CAM-H is also able to rotate over 25° in both the left and right direction to adapt for the intended path of the motorcycle.

Recommended Improvements

The final goal of the project was to develop the technology that would allow for a corner adapting motorcycle headlight to be produced. The technology is presented in a demo-stand, which provides real inputs to the system and enables the clear exhibition of the adapting headlight. Further testing could be done by installing the system onto a motorcycle and performing real-time experimentation of the system while executing various riding-maneuvers. This experimentation would allow for the data collection of motorcycle dynamics and lead to a more accurate dynamic model to be built into the system for improved aiming of the headlight. This testing would also prove the mechanical reliability of the design and would give us insight to possible improvements. Other improvements or follow up designs could be made with specific motorcycles in mind for original equipment manufacturing (OEM) purposes.



A motorcycle negotiating an S-curve.