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Development of Airbag Suit System for Motorcyclist

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ABSTRACT

Airbag suit is proven to prevent motorcyclists from having serious injuries especially spine, neck, ribs and collar-bone fractures. A common way to inflate the airbag is by attaching one part that called pin to the valve that controlling the airflow from canister to the airbag. An airbag inside inflated automatically when a pin connecting the jacket to the bike was pulled from its socket forcefully. However, unnecessarily inflation by a simple collision or falling down from the motorcycle waste the canister and replacing it is costly. The simple pull mechanism adds substantial delay to the system response which is undesirable during the impact. Thus, sensors activated valve is proposed to replace the mechanism. The project involved development of a control algorithm for the airbag inflation and performing analysis on the finished prototype. The system takes the inputs from IMUs and GPS for G-force and speed calculation. When a rider's position changed rapidly relative to the equilibrium position which is initially set during the calibration, the airbag will inflates. The calibration involved a sizable collection of samples, analysis and training to set the threshold in the algorithm which decides the emergency events. The implementation of sensory system reduces the response time which is critical during the impact.

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INTRODUCTION

Accidents involving two wheelers assuming a significant social cost, and their dynamics are really more complex and diversified than accidents involving only cars and their occupants since the kinematics of biker's body can be influenced by a wide range of variables. However, advancement in two wheeler rider safety has not kept pace with that of automobile rider safety. Injury could be reduced if some method of restraint could be provided to protect a rider in frontal collisions by controlling his trajectory and reducing his velocity before he hits the opposing vehicle (Finnis, 1990). Challenges in designing airbag system for motorcycle rider are that the rider is less likely to be in a fixed location with respect to the airbags at the point of impact and the lack of a supporting surface (Yuki and Takumi, 2014).

Background:

Currently, airbag shape used in Dainese design is in one-piece with a given name of D-air. It employs a single 4-liter collar that surrounds both shoulders and the back of the neck. Meanwhile, Alpinestars has a distinct understanding of locating the crucial parts of the body during collisions; their airbag is located on the shoulders only. Therefore, the air bladders used will be two, one for each shoulder. Second part is the mechanism of the airbag deployment. The quantity of canister used in the system is different in both companies. D-air has only one canister, so the airbag will inflate and deflate for only one cycle. Alpinestars's suit is equipped with a patented dual charge system so a racer can remount after the airbags have reset, and the system will provide protection in case of a second crash. The target of the system is to allow racer to continue the race again after got in an accident as the airbag will deflate after a period of time. Therefore, the suit will be not affecting the racer's performance on the circuit. A compact pneumatic inflation module, also in the hump, uses a "cold charge" of nitrogen to inflate the airbag in less than 50 milliseconds. The bag remains fully inflated for roughly 5 seconds, and then slowly deflates over a period of roughly 30 seconds.

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Prototype Design:

In this paper, Arduino Microcontroller is used to control the airbag inflation mechanism system. A GPS and IMU sensor is connected to the microcontroller to set the threshold of the speed and the G-force to execute the deployment system. Air canister linked to the airbag with solenoid valve. The racing suit prototype is almost the same as the products available in the market with minor modifications (Figure 1). The airbag need is implanted in the hump race. A low-cost CO_2 cylinder is used. This will make maintenance easier and affordable to the riders. LCD adapter will display the battery level and canister condition (Figure 2). The flow of the system is consisting of two subroutines, Display and Diagnostic subroutines (Figure 3). Display function will alert the user about current state of the gas canister, whether present or not. If solenoid valve is open, system will instruct user to replace the canister and reset the system.

Fig. 1: Position of the components on the racing suit.

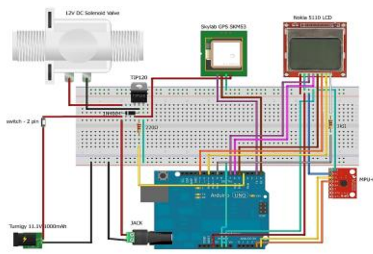

Fig. 2: Fritzing circuit for the airbag deployment system.

RESULTS AND DISCUSSIONS

CO_2 canister is designed to be installed at aero hump as it will ease users to replace the cylinder (Figure 4). Figure 5 shows the inner design concept for the aero hump. The position of the electronic circuitry components is very compact and small. The placement of the components also considers the risk of explosion, electromagnetic field (EMF) and other disturbances that may affect the system performance. Figure 6 shows the location of coupling between tube and airbag at the bottom of the jacket.

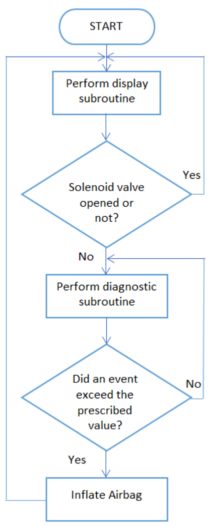

Fig. 3: Flowchart for airbag deployment in real-time system.

Fig. 4: Cylinder on aero hump.

Fig. 5: Electronics components.

Fig. 6: The airbag coupling.

The mechanism and algorithm used are different compared to the Alpinestars and Dainese. This system is much focusing on street motorcyclists and not for the race track. Basically, for the hardware design concept, the canister that contains high pressure CO_2 fluid is used to inflate the airbag in within 0.05 to 0.1 seconds. Solenoid valve with pressure rating of 60 bar was used to control the air flow. The most important part for an airbag deployment system is gyro sensor. MPU-6050 is used to calculate the gyro and accelerometer data thus can help to improve the system by combining the algorithm. The performance of an airbag inflation system is depends fully on the algorithms in aspects of efficiency, safety, and reliability.

Diagnostic pseudo code:
Read GPS data
If speed above 30km/h
Read accelerometer sensors data
If G-Force bigger that prescribed value limit
Send command open solenoid valve
Repeat Diagnostic

G-Force value can be calculated by using a vector formula in three axis of gyro and accelerometer readings. The graphs are based on cases that being determined in the beginning of the study that will be used to analyse inflation system. Cases that were studied are; G-Force values during the starting or riding a motorcycle, values during passing a bumper, and values during emergency braking. As the graphs display, there are random disturbance that makes the G-Force value not equal to one (Figure 8). As stated before, in this project three cases induced the readings.

The first graph was recorded during the ignition and speeding up the bike at the beginning (Figure 9). The rapid increment in gradient of the graph after some interval indicates the rider's G-Force reading during accelerating the motorcycle from the first gear to the third. Figure 10 shows G-Force values recorded during passing the bumper along the IIUM road. For the first rapid change point, that was for an emergency braking before the bumper and that resulted in only one drastic change of G-Force. The most significant interval that causes a rapid changing graph was recorded at speed of 40 km/h. This curve explained that receiving shock from bumper resulted in multiple vibration on elbows where the sensor was located. However, the motorcycle's mechanical absorber system could affect the repetitious vibration as well.

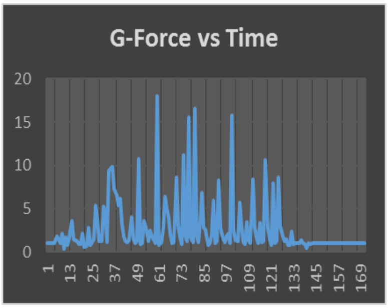

Fig. 8: G-Force values during indoor tests.

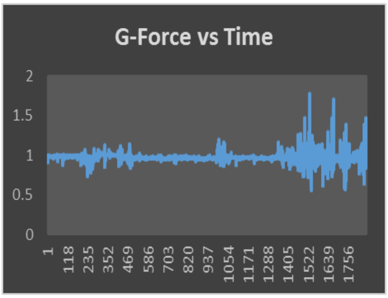

Fig. 9: G-Force values at the starting of riding motorcycle.

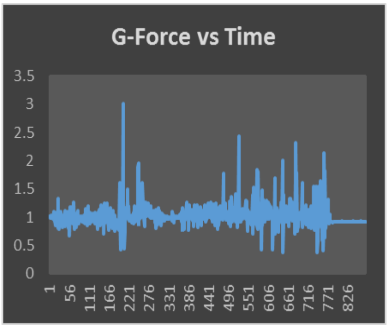

Fig. 10: G-Force values recorded during passing the bumper.

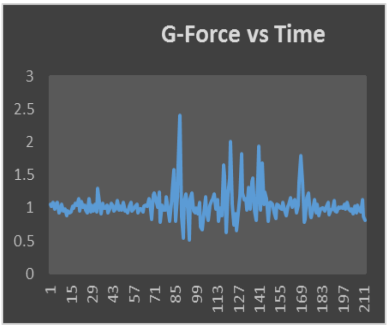

Fig. 11: G-Force values obtained during emergency braking.

Emergency braking is different compared to previous braking before the bumper (Figure 11). For the third case, emergency braking at 60km/h cause minor sliding that almost thrown off the rider. Referring to the graph, it explained the difference between emergency braking and previous two cases. In the graph, after major gradient changes, there were multiples of gradient changes overtime with some delay during sliding.

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Racing suits had been designed with attachment of elasticated leather and Kevlar by tailoring. Those materials used for flexibility of the rider yet limiting the design concept scope. Therefore, some materials like elasticated leather and Kevlar have to be implemented in order to make the specific areas. However, elasticated leather will limit the logo design area while Kevlar has limited colors. In order to implement the design concept while preserving the marketing aspects, a new material needed. It is called D-Skin leather that had been patented by Dainese. Therefore, the recommendation for future study is to implement this material into the design concept using the existing racing suit by zuldesigner. Outer zipper for aero hump should be included in the future concept design as it will ease removal of the hump race for system troubleshooting works and also canister replacement.

Besides that, aero hump design need to be modified to solid and flexible material so that it can withstand shock and reduce crash impact from the back. Moreover, it is also can be used to protect the circuitry.

Conclusion And Future Work:

In conclusion, development of the prototype is very important so that we can understand the riding behaviors and system requirements. It is involving airbag inflation system controlled by gyro sensors, airbag design suitable for street uses, and a system that use standard size of canister that easily available on markets. However, system installment onto the racing suit is not done as the tailoring will take time and the system needs to be tested for a longer period as to get an efficient and safe prototype. There are challenges in constructing the algorithm. Unlike the Dainese product for MotoGP racer, their algorithms are made out of repetition experiment for a few years. Airbag design should be custom-made to get better design and better overall performances.

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