

Sensors for airbag systems

Hebah Alobaidan

PAAET

Kuwait

ABSTRACT

This paper discusses a known concept, which has proven itself to be of crucial importance, as it continues to saves lives on a daily basis. This concept, is known as an airbag system. An Airbag is an automated vehicle safety restraint system for the passengers, which inflates itself upon impact, to protect the passengers. This topic involves continuous research and developments on its design, material, and performance in making this life saving safety device further efficient. However, success of any safety restraint device depends on its correct implementation and certain safety rules to be followed.

Keywords; Airbags; sensors; vehicles; restraint systems

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I. INTRODUCTION

Airbags were designed since 1951, and have aided in protecting vehicle occupants since they were made publicly available. Airbags, have proved their capability of enhancing passenger safety, and reducing the number of fatalities caused by car accidents. Hence, companies manufacturing cars are obligated to provide airbags in their vehicles, in order to promote passenger safety [1].

II. WHAT ARE AIRBAGS

An airbag is a mechanism that provides, allows a passenger's sudden stop in momentum to be compensated over a longer period of time, using a soft cushion. In other words, it prevents any damage to a passenger from their surroundings upon a sudden impact. Its purpose is to cushion occupants during a crash, protecting their bodies upon striking interior objects such as the steering wheel or a window. Hence, by reducing the force exerted by steering wheels, dashboard and other interior parts on the body it can lower the number of injuries. Airbags can protect a person's face, skull, neck and, in modern car airbags can also protect a passenger from hitting other passengers. There are different types of airbags, as shown in figure 1. Then again, they are located in different areas in a vehicle. Such airbags are:

- Frontal Airbags
- Shaped Airbags
- Side Airbags
- Side Torso Airbags
- Curtain Airbags
- Knee Airbags

- Rear Curtain Airbags
- Centre Airbags



Figure 1 shows the trends in computing [2]

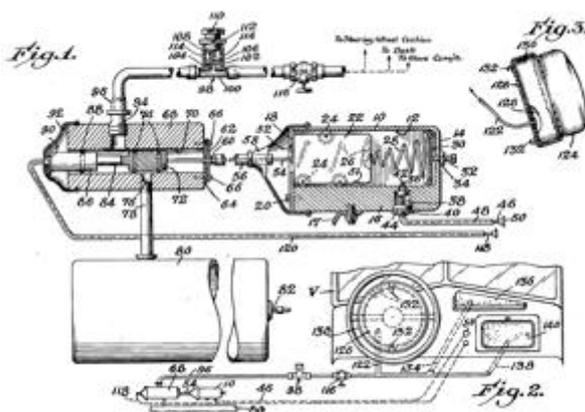
III. AIRBAG'S CONTRIBUTION TO ROAD SAFETY

Airbags have reduced driver fatalities in front-facing crashes by 29%. In addition to fatalities that were caused by frontal airbags with respect to ages of 13 and older have also been decreased by 32%. Another contribution from re-designing airbags is the deployment of side airbags. This type of airbag reduced car driver's risk of death in a side-crash scenario by 37%. SUVs side-crash has also decreased by 52% [3]. A total of 328,551 were saved, due to the presence of airbags from 1960 to 2002 [4]. This clearly demonstrates the remarkable advantages that can be obtained with airbag systems.

IV. HISTORY OF AIRBAGS

It started with John W. Hetrick from Newport, Pennsylvania. Based on his personal experience in an accident, he thought of a mechanism that would prevent passengers from being forced into the dashboard upon an accident. After weeks of designing, he filed his patent on August the fifth, 1952 for his design named "safety cushion". A year later receiving his US patent #2,649,311 on August 18, 1953. Several months before Hetrick's patent, a German inventor named Walter Linderer, applied an airbag patent. It was however, granted after Hetrick's patent, which is shown in figure 2.

Figure 2 Shows Hetrick's patent [5]



Companies such as Ford and General Motors started experimenting with air bag designs in the late years of 1950's. As a result of experimenting with their designs, they realised that there were two main issues, that would have needed to be resolved. These first issue was the ability to detect a collision in a reliable and accurate manner, while the second issue was the ability to inflate an airbag within forty milliseconds. Ford and General motors, realised that these issues were troublesome to overcome, and in an attempt to save on time and man power, they eventually lost interest in the concept and stopped their tests. Another issue that was discovered was, that airbag mechanism could cause injuries, which also needed to be avoided. This was followed by a ground breaking discovery invented by Allen K. Breed, with his electromechanical sensor. His sensor was based on a mechanical sensor with a ball-in-tube mechanism, used to detect a crash. It consists of a steel ball attached to a tube via a magnetic force applied by a magnet. When a crash occurs, the ball would free itself from the magnet, and roll into a tube, which allows it to come in contact with an electrical circuit. When the steel ball comes in contact with the circuit, it releases the airbag. Breed's airbag system managed to inflate an airbag

within 30 milliseconds through an explosion, utilising sodiumazide [6]. Figure3, shows the airbag exploding through the utilisation of sodium azide. This was then used for the first time by Breed's corporation on a Chrysler vehicle. According to Breed's New York Times obituary Breed continued his innovation with numerous patents for improvements, helping to turn Breed Corporation into one of the world's largest suppliers of car safety systems [7].



Figure 3 Shows a deploying airbag [7]

In 1999, Breed was the third-largest supplier of automotive safety systems in the world, with sales of \$1.4 billion, Mr. Breed was inducted into the Automotive Hall of Fame in Dearborn in that same year, as an appreciation for his electromechanical air bag sensor, set off by an electromechanical sensor, a precursor of the electronic sensors in our market today[8].

V. HOW WAS THE AIRBAG REVOLUTION ACCOMPLISHED

Everything is related to the laws of physics. So is the concept of an airbag system, which is controlled by the laws of motion. A moving object has *mass* and *velocity*. The product of these two principles, is *momentum*, anything that has a momentum has *kinetic energy*. The heavier the car, and the faster it is moving, the larger the kinetic energy is. This energy affects everything travelling with the object, and as soon as a moving object stops, this kinetic energy needs to be released. This principle is after Newton's first law of physics, which mentioned that things that are moving, will tend to move until something of an equal force or greater stops them. Even with the restraining functionality of a seatbelt, a passenger's head will still move due to the kinetic energy, while the body

is restrained. This is where the functionality of an airbag fits in. Hence, the airbag needs to reduce the effect of the kinetic energy of the occupant. This is accomplished in two major ways;

a) by the increase of the time interval for the force that was being applied on the occupant, allowing the body's momentum to come to an end slower.

b) by spreading the force of impact over a larger area of the body, hence reducing the intensity of the impact.

VI. AIRBAG SYSTEM WORKING PRINCIPLE

Vehicle occupants rarely know how their airbag system works. In fact, upon informing individuals that, if an unfortunate accident may happen, his life would depend on the performance of a chemical explosion, they would certainly be shocked. An airbag system consists of three main parts, which are shown in figure 4, and listed below:

1. Sensing Unit (Sensor)

A Sensor is also known as a transducer; it produces a signal (commonly electric) from the process being monitored which can be used as an indicator of the magnitude of the input quantity. These sensors are placed in various locations to indicate different changes in properties.

2. Electronic controller unit

Receives important information from the sensing unit. Such information provides the type of collision, the angle of the collision, and the severity of the impact. This information is then diagnosed into an algorithm which has a set of requirements that need to be met. Once these requirements are met, it considers the crash dangerous, it triggers the airbag module to inflate the airbag. Such a condition is known as the airbag's triggering threshold. These sensors are calibrated for each specific vehicle, dependent upon the unique vehicle characteristics, provided by the manufacturer. This also includes the specific characteristics that come with different sensors, which different algorithms used. Hence, it is quite difficult to determine the triggering characteristics. However, vehicle manufacturers always set a velocity threshold for airbag deployment, which varies among vehicles. The actual value of these velocities varies for each vehicle. A possible example of this air bag velocity threshold is shown Figure 4 shows an example where any impact below 8mph would not deploy the air bag, while any impact above 14mph would. However, they are in between is the "may deploy" range, where the deployment of the airbag, is strictly impact dependent [p].

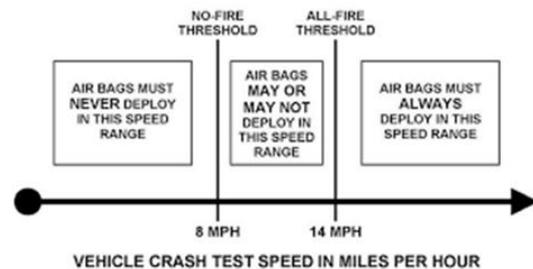


Figure 4 Shows airbag threshold [10]

3. Airbag module

The airbag module contains a light, yet durable fabric that makes up the airbag. This module also contains the airbag's inflation mechanism, and is located in the steering wheel. This component remains idle unless a signal is given by the electronic control unit, allowing it to deploy. Upon deploying it rapidly fills up, and spreads over a wide area, absorbing the impact it takes of the passenger. Thus, allowing the passenger's impact to be reduced over a period of time, on a large surface.

VII. SENSOR TYPES

It is important to mention that an automated restrain system does not rely on one single sensor. This is not the case, as accidents come in different forms, scenarios, different angles of impact and at different speeds. Thus, the need of a variation of interconnected sensors to inform the electronic controller of the type of impact and location of impact. This is why, there are several sensors in modern airbag systems. There are two main types of airbag sensors, mechanical and electronic. The different types of sensors used in airbag systems are; accelerometer sensors, gyroscope sensors, weight sensors and ball-in-tube. Due to modern electronics such sensors come in small sized circuits, which can be placed freely in a vehicle. Two important sensor types are:

1. Mass-type sensor

This type of a sensor is fitter to the front side of the vehicle, where direct collisions are more likely to occur. The sensor is located within the engine of the vehicle, and another similar sensor is located in the passenger's area of the vehicle. The second sensor is known as the safety sensor, and it determines how dangerous the impact is. Based on the intensity of the impact, the sensor decides if the impact exceeds the threshold level. Such sensors are also known as; inertia sensors. Inertia sensors working mechanism is related with the changes of acceleration in a moving vehicle. As soon as it detects a decrease, it generates an electrical signal. This sensor is illustrated in figure 5. This figure shows that when the car comes to a sudden stop in motion due to an accident. The sensing mass is forced forward, due to

its momentum. It is forced into the gold-plated contacts, and as a result, the ball comes into contact with the electrical terminals at either side of the metal ball. This prompts the controller unit, of a collision.

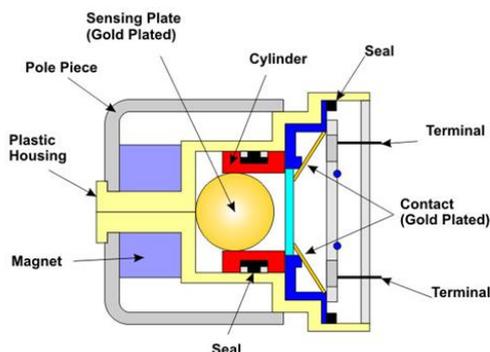


Figure 5 Mass-type sensor [11]

2. *Roller-type sensor*

A weight is connected to a spring made of coil. Upon an impact, the weight will be forced to move forward, which increases the tension on the spring. This allows it to manipulate the electrical circuit, that closes the sensor's contact. In this sensor, the sensor must be activated in order to close the electrical circuit. This only allows the deployment of the airbag. Figure 6, depicts a roller type sensor.

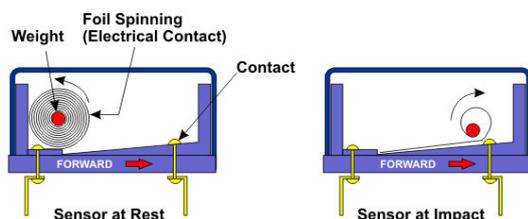


Figure 6 roller-type sensor [11]

VIII. INJURIES AND LIMITATIONS

There has been a lot of controversy about whether airbags, are in fact dangerous. It is important to realise, that airbags are a supplementary system that works together with seatbelts. They're specifically designed in such a way, that the soft cushion expands on a distance near to the driver's natural position during a crash. This is of course, close to the seat itself due to the restraint provided by the seatbelt. In such a scenario, the passenger's face lands on the soft part of the cushion normally and avoids any kind of injuries due to the airbag. If this is not the case, then it is usually when the driver is not wearing his seatbelt. In this scenario, the driver is forced forward, closer to the steering wheel,

where the airbag may deploy against his face, causing him an injury.

This is also the case when children are the passengers. Airbags are designed for adults, which means that they can be dangerous for younger passengers, whom are smaller in size. Hence, younger passengers are forced by traffic laws to embark the backseats of a vehicle. If an airbag comes into contact with a younger passenger, it may cause a serious injury, where in severe situations, it can be fatal. The dangers of an airbag can be fatal in the following cases [12]:

- An infant in a rear-facing car seat
- A young child riding in front on an adult's lap
- A child riding without a seatbelt.
- A driver sitting close to the steering wheel.
- Any passenger sitting very close to the dashboard.

IX. FUTURE OF AIRBAGS

The future of airbags is promising. This can be concluded from the advancements made over time. Sensor have developed and inflatable airbags themselves have developed as well. This contributed to the overall performance of airbag systems. Other factors such as the development of technology will participate as well. It is anticipated that the next generation of devices will also incorporate the entire airbag deployment circuitry that in a single chip. With the rise of nanotechnology, it is only a matter of time until such sensors become integrated with the entire exterior of the car. A similar example can be seen from figure 6, as it shows cars with external airbags. This was cars avoid receiving damage as well. In fact, it also secures the life if the pedestrians surrounding the vehicles.



Figure 7 External airbags [13]

Wearable computers are also increasing nowadays. It might be possible to integrate our wearable computers such as watches and clothing sensors with the safety mechanism in a car. Hence, providing extremely accurate sensing mechanisms for airbags. The Omni-suit is an example of such a concept, as it provides a wearable acceleration sensor.



Figure 8 Omni-guard: The wearable sensor [14]

The wearable suit is for individuals that work in high altitudes, which is dangerous if this individual may slip or fall. The Omni-guard suit acts as a wearable airbag, as shown in figure 8. Upon falling, the sensors detect the change in acceleration and deploy a safe surrounding airbag to protect the individual's body. Thus, avoiding fatal injuries or even death [14].

X. CONCLUSION

It is clear that airbags have made a remarkable progress over the past centuries. Companies are considering car safety a competitive field, as each manufacturer promotes safety in his own methods. Such competitiveness leads to secrecy in production and manufacturing of airbags. Having a yearly united vehicle safety conference would contribute to the greater good of providing smarter, faster, more reliable and safer airbag systems. This pushes computer science students to design enhanced algorithms, and electronic engineering students to provide a better integration among different sensors. Pushing the current performance to a higher level.

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