The Engineering of Automotive Airbags

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Thousands of lives are saved during high-speed automobile accidents due to airbags. Exactly how does the airbag deploy at such a high speed, and what trends in airbag technology should we look forward to in future developments? The development of the automotive industry has lead to enormous developments in safety, specifically airbag design and technology. This article details the development or airbags in cars, the design of airbags (chemically and mechanically), as well as the future of airbag safety.

Introduction

Henry Ford revolutionized the world in the 1920s by using an assembly line technique to produce cars that everyone could afford. His "Model T" prototype spawned a new era in which personal freedom and independence was expressed through the ownership and usage of an automobile. The Model T was simple in design and function by today's standards; it did not accelerate nor brake quickly and did not handle very well. In fact, it had a permanent convertible-style top that offered no shelter from weather, and it did not have safety belts or other constraining devices. Shortly after its creation, Ford stated, "There is no need for further development in motorcars, for I have perfected the modern automobile." Little did Ford realize that he had pioneered a machine that would undergo decades of technological safety revisions.

Years after the Model T was assembled, the seat belt was implemented in some cars as the only form of passive restraint. People were reluctant to use the belts at first, claiming that they were uncomfortable and restricted movement in the car. However, statistics have proven that seat belts are responsible for saving lives in automobile accidents that would have otherwise been lost. Most regions in the United States and many other countries now enforce mandatory safety belt laws.

Although airbags have never replaced seatbelts, they were designed to provide maximum safety when used in combination with seatbelts. It is important that they be used at the same time as safety belts because most airbags only work in front end collisions faster than 10 miles per hour. Regardless, airbag technology is currently undergoing innovative revisions and improvements at a phenomenal rate, while seatbelt design has remained stable throughout the years. This article will explore the historical development of airbags, explain the engineering behind the airbag's deployment technology, and speculate on safety concerns and the future of airbags.

Historical Development of Airbags

Airbags have been under development for many years. Their purpose is to restrain automobile drivers and passengers in a collision, whether or not they are wearing seat belts. Early airbags were mainly used as inflatable crash landing devices for airplanes. The first patent on an airbag was filed during World War II, and the automobile industry started researching airbag technologies in the late 1950s. However, there were many more difficulties in the development of airbags than anyone had expected.

The early airbag designs were impractical and expensive. The main concern for design engineers was for the storing and releasing of a compressed gas. Issues were raised such as where to store the container for gas in the car, how to develop a mechanism that allows the gas to expand quickly, and how to make sure that the stored gas would have a shelf life at least equal to that of the car. In addition, the automobile industry found that in order to be effective, an airbag must deploy and inflate within 40 milliseconds. The airbag systems must also be able to differentiate between major and minor collisions.

These issues were addressed in the 1970s with the invention of small propellant "inflators," devices that initiate a chemical reaction that releases hot nitrogen gas into the airbag. This device was a major stepping-stone in the development of airbag technology, as it has enabled the common use of commercial airbag systems that have been available since the late 1980s.

Airbag Engineering

One should review some basic physics concepts to better understand the engineering of an airbag. All moving objects have momentum, which is the product of the mass and velocity of an object. According to Newton's first law of motion, every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it. Newton's third law of motion says that for every action there is an equal and opposite reaction. Moving objects have momentum, which is the product of the mass and velocity of an object. Unless an outside force acts upon the object, it will continue to move at its initial velocity (both speed and direction). Cars consist of several objects, including the vehicle itself, loose objects in the car, and the passenger(s). Unless they are restrained, the car's contents will continue moving at the car's velocity (Newton's first law), even if the car is stopped by a collision (Newton's third law).

A constant force in the opposite direction of the car's motion is required to safely stop the momentum of objects inside a car. When a car crashes at a high velocity, a very large force is needed to stop the objects inside because the car's momentum has changed instantly while the passenger's has not. Thus, the goal of seatbelts and airbag systems is to help stop passengers with as little damage to the passenger as possible.

The airbag system must be engineered to work with the space between the passenger and steering wheel in a fraction of a second (milliseconds). The airbag must inflate fast enough, and then deflate at the right time, slowing the passenger's speed to zero evenly rather than forcing an abrupt halt to motion (to prevent injury to the passenger). In addition, the airbag unit must also stay intact at low-velocity collisions. There are cases where passengers have been injured not by the low speed impact, but by the airbag's powerful deployment into their body. All these constraints must be taken into consideration in the design of a crash sensor that can detect collisions and will trigger the bag to inflate.

The simplest design for the crash sensor is a steel ball that slides inside a smooth cylindrical hole. The ball is held in place by either a permanent magnet or a stiff spring, which inhibits the ball's motion when the car drives over bumps or potholes. Inflation happens when collision forces greater than running into a brick wall at 10-15 miles per hour occurs. When the car decelerates very quickly, as in a head-on crash, the ball suddenly moves forward and activates an electrical circuit. This electronic circuit initiates the process of inflating the airbag. The electronic sensors use a microscopic accelerometer (a device that measures acceleration) that has been etched onto a silicon chip.

During the airbag's deployment, a series of chemical reactions take place between highly toxic sodium azide (NaN3), potassium nitrate (KNO3), and sodium dioxide (SiO2) to inflate the bag. After the crash sensor has triggered an electric circuit, it creates a high-temperature condition necessary for NaN3 to decompose. During it's decomposition, NaN3 produces sodium metal (Na) and nitrogen gas (N2). A rapid pulse of the hot nitrogen gas (N2) is released from a gas generator at up to 200 miles per hour, filling the airbag, which is made of thin nylon fabric. The nitrogen gas then converts the highly toxic NaN3 to harmless gas. The KNO3 and SiO2 are present to remove the highly reactive and potentially explosive sodium metal (Na) by converting it to a harmless material. This whole process happens in approximately 1/25th of a second. Ideally, the body of the driver or passenger should not hit the airbag while it is still inflating. In order to sustain maximum protection, the airbag begins to deflate (i.e. decrease its internal pressure) before the body hits it. Otherwise, the high internal pressure of the airbag would create a surface as hard as stone-- not the protective cushion you would want to crash into. (Casiday, Frey)

Safety and the Future of Airbags

Crash studies by the National Highway Traffic Safety Administration (NHTSA) show that airbags reduced death fatalities in a direct frontal crash by about 30 percent. The NHTSA also estimates that airbags prevented about 600 fatalities in 1995 alone. The increasing trend towards requiring airbags in all new cars reflects the public's better realization of the airbag's benefits. As more new cars come standardized with airbags, the rate of deaths in high-speed accidents will decrease.

Although there seems to be a beneficial correlation between airbag use and lives saved in accidents, there are rare cases where the airbag's deployment kills or seriously injures people in the car. Usually occurring in low-speed accidents, the airbag can deploy and cause more damage to the passenger than had it not deployed. These exceptions to the rule have inspired an ethical dilemma that questions the usefulness and "safety" of airbags. Do the benefits of airbags outnumber the disadvantages? According to a study, deaths among drivers using both airbags and seat belts are 26% lower than among drivers using seat belts alone (Casiday, Frey). In spite of these optimistic findings, safety advocates continue to evoke the same controversy that surrounded seat belt use in its early years, and airbags are now the subject of serious government and industry research and tests.

In spite of the controversy surrounding airbag safety, car manufacturers continue installing airbags on both driver and passenger sides, both of which has been required since the 1998 model year. In addition, side- and rear-mounted airbags are being developed and used in cars. Head airbags are the newest innovation, and were first made available on all 1999 models of BMW cars. Using the same technology as steering wheel airbag technology, the sausage-shaped bags are located on the seat's headrest and are supposed to offer greater protection from side collisions and rollovers. Some experts say that within the next few years, our cars will go from dual airbags to having half dozen airbags. These cars will undoubtedly reflect the improved safety features in the price tag, but are consumers willing to pay more for an extra measure of safety?

Airbags have also been used in spacecraft. In 1997, NASA installed a $5 million airbag on its Pathfinder spacecraft, which was the first spacecraft to reach Mars since the 1970s. The airbags cushioned a "crash landing" on the planet at a collision speed of approximately 65 miles per hour. Thus, safety bags have benefited other industries.

Engineers continue designing airbags that might better protect automobile passengers as they also explore ways to make the devices smaller. Hopefully, these advancements will be available at affordable prices for everybody. With the advent of digital technology, the possibilities of safety provisions are endless. But there is a warning: no matter how many airbags in your car, you still need to wear a seat belt.

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