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Earthquake Airbags, New Devices to Save Lives in Earthquakes, Tornados and Similar Disasters Resulting from Building Crashes

Amir Hashem Shahidi Bonjar
Helli High School for Exceptional Talents, Kerman, Iran

Abstract: Earthquake Airbag (EA) is a new terminology being introduced for the earthquake literature of the world. According to literature surveys, this terminology has not been used previously. Based on many scientific reports, fatality rates are lower in vehicles equipped with airbags than unequipped ones. Accordingly, it was postulated that similar structures can be adopted in buildings to protect people and lower human casualties in building crashes. The data collected from simulation of collision-impact on fragile objects revealed that the safety advantage of airbags is that they can reduce impact injuries upon indoor people from falling debris in earthquakes and building crashes resulting from tornados, hurricanes or similar disasters.

Key words: Earthquake Airbags, Impact Injuries, Tornados, Hurricanes, Safety Appliance

INTRODUCTION

The development of airbags began with the idea for a system that would restrain automobile drivers and passengers in an accident. The road from that idea to the airbags we have today been long, and it has involved many turnabouts in the vision for what airbags would be expected to make[1]. Today, airbags are mandatory in new cars and designed to act as a supplemental safety device in addition to a seat belt. Airbags have been commonly available since the late 1980's. The automobile industry started in the late 1950's to research airbags and soon discovered that there were many more difficulties in the development of an airbag than anyone had expected. Crash tests showed that for an airbag to be useful as a protective device, the bag must deploy and inflate within 40 milliseconds. The system must also be able to detect the difference between a severe crash and a minor fender-bender. These technological difficulties helped lead to the 30-year span between the first patent and the common availability of airbags [2-4]. Reports indicate that airbags have saved lives and have lowered the number of severe injuries. These statistics are continuing to improve, as airbags become more widely used [1, 5-7]. Nevertheless, as the recent reports have shown, there is still a need for development of better airbags that do not cause injuries. Also, better public understanding of how airbags work will help people to make informed and potentially life-saving decisions about using airbags. The overview of how airbags work is that timing is crucial in the airbag's ability to save lives in a collision. An airbag must be able to deploy in a matter of milliseconds from the initial collision impact. It must also be prevented from deploying when there is no collision. Hence, the first component of the airbag system is a sensor that can detect head-on collisions and immediately trigger the airbag deployment. One of the simplest designs employed for the crash sensor is a steel ball that slides inside a smooth bore. The ball is held in place by a permanent magnet or by a stiff spring, which inhibit the ball's motion when the car drives over bumps or potholes. However, when the car decelerates very quickly, as in a head-on crash, the ball suddenly moves forward and turns on an electrical circuit, initiating the process of inflating the airbag[1, 8].

Once the electrical circuit has been turned on by the sensor, a pellet of sodium azide (NaN_3) is ignited. A rapid reaction occurs, generating nitrogen gas (N_2). This gas fills a nylon or poly amide bag at a velocity of 150 to 250 miles per hour. This process, from the initial impact of the crash to full inflation of the airbags, takes only about 40 milliseconds. Ideally, the body of the driver (or passenger) should not hit the airbag while it is still inflating. In order for the airbag to cushion the head and torso with air for maximum protection, the air bag must begin to deflate (i.e., decrease its internal pressure) by the time the body hits it[1, 9].

Chemical Reactions Used to Generate the Gas to Fill the Airbag: Inside the airbag is a gas generator containing a mixture of NaN_3, KNO_3, and SiO_2. When the car undergoes a head-on collision, a series of three chemical reactions in the gas generator produce gas (N_2) to fill the airbag and convert NaN_3, which is highly toxic (The maximum concentration of NaN_3 allowed in the workplace is 0.2 mg m^{-3} air.), to harmless glass (Table 1). Sodium azide (NaN_3) can decompose at 300°C to produce sodium metal (Na) and nitrogen gas (N_2). The signal from the deceleration sensor ignites the gas-generator mixture by an electrical impulse, creating the high-temperature condition necessary for NaN_3 to decompose.

Table 1: Compounds Involved in the Chemical Reactions in the Gas Generator of an Airbag (Stoichiometries Quantities are not shown Revised from Casiday and Frey, [1])

Gas-generator reaction	Reactants	Products
Initial reaction triggered by the sensor	NaN_3	Na N_2 (g)
Second reaction	Na KNO_3	K_2O Na_2O N_2 (g)
Final reaction	K_2O Na_2O SiO_2	Alkaline silicate (glass)

The nitrogen gas that is generated then fills the airbag. The purpose of the KNO_3 and SiO_2 is to remove the sodium metal (which is highly reactive and potentially explosive, as you recall from the Periodic Properties Experiment) by converting it to a harmless material. First, the sodium reacts with potassium nitrate (KNO_3) to produce potassium oxide (K_2O), sodium oxide (Na_2O), and additional N_2 gas. The N_2 generated in this second reaction also fills the airbag, and the metal oxides react with silicon dioxide (SiO_2) in a final reaction to produce silicate glass, which is harmless and stable. (First-period metal oxides, such as Na_2O and K_2O, are highly reactive, so it would be unsafe to allow them to be the end product of the airbag detonation)[1, 10, 11].

Airbags is also used in aerospace engineering. The Mars Pathfinder airbag system was designed to protect the lender regardless of its orientation upon impact with the surface of the planet. The system also was designed to handle lateral movement as well as vertical descent.

The result is a robust system capable of landing in rugged but scientifically interesting locations on Mars. Development of the airbags required significant design and test work, but the qualification program for the system was completed in April of 1996, 8 months prior to launch[12, 13].

Feasibility of airbags to prevent shipping damage of fragile goods is also well demonstrated. Ride Rite® inflatable bags are developed to eliminate shipping damage and associated expenses. They are constructed of multiple layers of high strength extensible Kraft paper, and the outer ply of the 6 and 8 ply is coated with polyethylene film for added protection against loss of air pressure. Ride Rite® Airbags are designed in different sizes and strengths to meet the required safety needs[14].

MATERIALS AND METHODS

Data Collected from Human Casualties in Bam Earthquake: The Bam earthquake of December 26, 2003, with a magnitude of 6.5 Richter, occurred at 05:26:26 local time around the city of Bam in the southwest of Iran. The earthquake happened when most of the inhabitants were sleeping, that can be one of the causes of the great life loss. Approximately 70% of buildings in the city of Bam have collapsed, leaving many trapped and others homeless. The number of victims was declared officially to be more than 25,000, more that 50,000 people are declared to be injured and about 100,000 people became homeless[15-20].

Airbags and Fragile Tools used for Collision Simulations: Simple simulation of collision-impact on fragile objects as empty glass bottles was performed with and without an air bag as protective cushions. Heavy objects as bricks, concrete blocks and metal solid beams were used to demonstrate the behavior of falling debris during early stages of an earthquake in a general building. The objects were dropped from a height of 2-3 m on the fragile objects with and without air bags as protective cushions. Each experiment performed in triplicate and the results were recorded. Presence of shattering or breakages of the fragile objects was recorded as negative protection and lack of breakage evaluated as positive protection due to the presence of airbag cushions.

RESULTS AND DISCUSSION

In all of the collision simulation studies, the results indicated that collision-impact on fragile objects led to shattering or breakages of the fragile objects (negative protection) when the airbag was not present, but the presence of airbag cushions revealed a lack of breakage (positive protection) on the objects used in the test. To postulate this behavior on people, it can be expressed that airbags help reduce injuries by spreading the force over a larger area of the body. If the object crashes directly into the body, all the force will be applied to a localized area on the body that is the size of the object, and serious injuries can occur. However, when the body is protected by an airbag, which is larger than the object, all the force from the airbag on the body will be distributed (spread) over a larger area of the body. Therefore, the force on any particular point on the body is smaller.

How Does the Presence of Earthquake Airbags Actually Protect People?: Earthquake Airbags decrease the force on the body and spread the force over a larger area. The objective of the airbag is to lower the number of injuries by reducing the force exerted by the falling object on any point on the body. This is accomplished in two ways; by increasing the time interval over which the force is applied and by spreading the force over a larger area of the body. Newton's familiar first law of motion says that objects moving at a constant velocity continue at the same velocity unless an external force acts upon them. This law, known as the law of inertia[8], is applicable in collisions. When a building crashes and debris fall with velocity, they come to a stop when hitting the people, there is a force exerted on the body to change its velocity and injuries result since this force is very large. Airbags protect the person by applying a restraining force to his body that is smaller than the force the body would experience if it is hit suddenly, so the force would spread over a larger area and hence there would be reduced injuries in sudden impacts.

Nitrogen is an inert gas whose behavior can be approximated as an ideal gas at the temperature and pressure of the inflating airbag. Thus, the ideal-gas law provides a good approximation of the relationship between the pressure and volume of the airbag, and the amount of N_2 it contains. A certain pressure is required to fill the airbag within milliseconds. Once this pressure has been determined, the ideal-gas law can be used to calculate the amount of N_2 that must be generated to fill the airbag to this pressure. The amount of NaN_3 in the gas generator is then carefully chosen to generate this exact amount of N_2 gas[1, 10]. Helium is a noble gas that is not used to fill airbags because there is no convenient and economical way to generate a large amount of He gas quickly.

Obviously, people trapped under EAs are less vulnerable to injuries resulting from falling materials off ceilings and walls, so there are fewer chances of death, smashing, bone breakage, and more chances for their survival. After the onset of an earthquake, since EAs would inflate very quickly and occupy most of the room, the height of falling for detached debris decreases, the intensity of impact on people would be much lower and certainly leads to reduced impact injuries.

Proposed Specifications for Earthquake Airbags: To industrialize and commercially produce EAs, the following criteria should be regarded in their productions properly:

- The specifications of EAs as shape, number and inflated volume should be designed according to the structural specifications of the buildings. The inflated shapes of EAs can be designed as cylindrical, spherical, cubic, mattress or others.
- All EAs should be equipped with a Trigger Sensor (TS) to initiate the inflation upon receiving a special level of sudden impact intensity. The TS should be equipped with adjustable device that can be set according to the building structural resistance.
- To avoid suffocation of trapped people underneath, design of surface topology of EAs should not be smooth. In other words, the EA surfaces should have grooves, protrudes or similar structures not to block nose or mouth airways but to allow air passing for breathing.
- Composition of EAs should be designed for fire-resistant materials for some buildings are set into fire after the crash.
- Inflating gas of EAs should have an inert nature, being fired-safe and if released through rapture, not causing respiration problems or suffocation.
- EA can be introduced in market as portable packages designed according to building specifications. EA packages may be regarded as a new home appliance throughout the world to reduce injuries and life losses upon unpredictable hazards in building crashes resulting from earthquakes, tornados, hurricanes or similar disasters.
- Installation positions, numbers and inflation direction of EAs should be also optimized. They may be installed on ceilings, certain heights of walls, or even on portable stands. The last form may be appropriate in bedrooms since at early stages of impact it expands as an inflated mattress forming a covering shield over sleeping people.
- To increase EAs security, they should be well designed from materials being resistant to punctures and shearing.

The efficacy of EAs would be more prominent during the sleeping period at night since there are fewer chances for escape to safe zones.

Other advantages of EAs are in life-saving attempts following the crash. According to the present observations in the Bam earthquake (Bam, Iran, 26 December 2003), the attempts taken by resuscitation teams using heavy machineries as mechanical shovels or loaders, caused collapse of semi-crashed buildings over trapped people which resulted in the loss of many lives. Coverage of EAs upon trapped people certainly reduces impact injuries in such after-crash resuscitation attempts.

The author likes to mention that manufacturing of the proposed EA device is not allowed by any person or factory without the written permission of the author.

The author hopes that these new devices would evoke new research avenues to combat or reduce life losses of hazards in building crashes resulting from earthquakes, tornados, hurricanes or similar disasters which humans face throughout the world all year around.

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