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ORIGINAL ARTICLE

Investigation of the Causes of Car Battery Explosion

ESTEBAN GONZALEZ, MAHMUD HASAN

Computer Science and Engineering Technology (CSET) Department, University of Houston-Downtown (UHD), Houston, Texas-77002, USA

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ABSTRACT

Anyone who owns a vehicle has certainly dealt with a dead battery at least several times in his/her life, however he/she might not know the hidden hazard of explosion of a battery. Therefore it is very important to know proper handling of battery to prevent a battery from exploding. This study is intended to inform people on proper battery handling, causes of an explosion, and how accident investigations can be conducted. To do this, this work will present information that informs people on causes, investigation, and corrective measures in battery use. The main methods used in this work are research, published literatures, and analysis that will aim to create awareness that is easy to understand. This paper will cover causes of battery explosions, techniques used in investigations, and preventative measures. The expected results of this paper are to find multiple reasons why a battery may explode, various techniques used in investigations and find ways that prevent a battery from exploding.

KEYWORDS: *Car battery, Explosion, Jump start, Battery posts, Battery terminals, Battery fluid, Accident investigation, Fragments*

Corresponding author: Mahmud Hasan
E-mail: ***hasanm@uhd.edu***

INTRODUCTION

Anyone who owns a vehicle had to deal with their battery not starting the vehicle at least once in a lifetime. When this occurs people either try to remove in order to buy a new one. Often, try to charge it themselves or remove to take it to the auto parts store to get it charged. The danger part of this is that car batteries may explode without any type of warning. That is why this topic is highly important and needs close attention. There are other pieces of literature that cover this topic; however, it seems that not a lot of them have covered this topic with a lot of depth and detail. The application areas for this work will be to discover factors that may contribute to a battery explosion, determining how an investigation is conducted when a battery ends up exploding, and finding recommendations for people to take in order to reduce the risk of a battery explosion. With these application areas on mind, the analysis, investigation, and recommendation parts of an accident investigation will be covered (Oakley, 2012).

The main reason of interest in this work is because one the authors (Esteban Gonzalez) in this paper have been working in an auto parts store for a little bit over a year and dealt with batteries every time. When someone first gets hired, he or she has to take a foundations class where they explain what the company is about and some of the safety precautions that have to be taken when someone is working. In that class they inform the new employees that everyone needs to wear a goggle, an apron, and gloves when he or she does testing the batteries and putting the batteries to charging station inside the store. The training lessons also include, some lessons learned based on accidents that have happened while dealing with batteries, like when battery acid fell on someone's shirt and when someone did not place a battery correctly on the shelve and it fell, leaving part of the floor filled with battery acid. In these cases, management is notified of what happened and they throw some chemical compounds that they possess that absorbs the acid off the floor. Whereas the person has to throw away that shirt because the acid left the shirt with a lot of holes which were caused by acid spills. There are other events that happened at work too that confirm how dangerous car batteries can be, however those are just a few examples.

OBJECTIVES

The present study aimed to determine the impact of automotive battery explosions that include the identification of multiple causal factors, how to properly work with a battery of this kind and how battery explosions are investigated when they occur. As mentioned in the introductory part of this work, dealing with car batteries can be dangerous and battery explosions are common due to the fact that most people try to fix the batteries themselves. Therefore, the best option to combat this issue is to inform people on these topics in order to reduce the number of car battery explosions. The information will be provided in form of text supported by figures in order to make it easier for people to understand and produce a more effective work. Therefore, the main objective for this work is to inform in the clearest and simplest way as possible to help the people understand how to handle a battery and explain how simple mistakes can cause major injuries.

LITERATURE REVIEW

This work will be based on the information gathered from three distinct articles which are full of information but also have their flaws and may be missing key information. The first article that is reviewed is titled, "The forensic investigation of a lead acid battery explosion," by The Forensic Experts Group. This article gives an example scenario where a car battery explodes, the article is divided into sections which are background of case, laboratory findings, gassing of hydrogen, ignition sources etc. This article does a great job identifying some causes that can lead to a battery explosion and identifying some of the laboratory techniques that are used to determine the causes of the explosion. However, this text does not identify any preventative measures and the reader has to infer the preventative measures based on the causes that are provided in this case scenario. The other flaw

this article has, it only uses one case scenario, limiting to just one set of causes when there can be different situations that can lead to a battery explosion. The scenario this article uses is the one that has to do with the act of overcharging and not charging the battery in proper condition. However, there can be many more scenarios like improper jump starting or battery installation that can also be common.

The second article that is used to gather information is, "Investigating Automotive Battery Explosions," by Charles Roberts. This article is very similar to the first one, which means that it covers mainly investigation techniques and the causes of the explosion. However, this article is supported by various pictures of battery fragments and diagrams of how most batteries are built and batteries that have exploded to show a visual presentation of such objects. This piece of text does well in explaining the different causes a battery may explode, giving a presentation of how that looks like and explaining the techniques that are used in investigating each case scenario. Unlike the first article this article uses multiple scenarios giving readers more ideas of what can cause a battery explosion. However, this article does not go into detail on preventative measures people can take which have to be inferred by the reader based on the causes identified.

The third article, where the work is went over from the LA Times and is titled, "How to Avoid Battery Explosions (Yes, They Really Happen)." This article is easier for the common person to understand since it does not use any scientific or technical terms that would be hard to understand for most people. Statistics on the most common causes of battery explosions, like jump starting, refilling the battery with fluid and handling battery cables, are provided, and covered by mentioning some safety tips to prevent this from happening more often. The tips that are given by this article are easy to understand and follow e.g. putting the cables on the dead battery first when a jump start is needed and cleaning the battery cables and posts regularly. All of this means that this piece of text does a great job identifying the most common causes and recommending preventative measures, something the previous articles did not do, but does not go over how each cause is investigated when a battery explosion occurs. Another important part that is missing from this article is not providing visual representations of the content the text talks about, whereas visual figures could make it even easier to grasp to the information provided.

RESOURCES USED DURING THIS RESEARCH

The way this work is planned is by conducting research online and gathering pictures in order to prove claims in a more effective way. The information that is gathered from online sources will be complemented by background knowledge that is gained working in auto parts for a year. The research articles are gathered from different credible sources and put together to create a work that covers causal factors, investigative techniques, and recommend-dations in the form of preventative measures. The online resources are the articles that have been reviewed in the previous section of this work, using the information that is relevant for the purposes of this work. Since the articles are missing important parts, however those parts can be found in the other articles. The research part of this work is well covered and reinforced by some of the knowledge and experience collected while working in a auto parts store. For instance, the first two articles that are reviewed do not cover recommendations to prevent battery explosions, however the third article that was reviewed did cover such things as preventative measures. This can be reinforced by recommending the use of the personal protective equipment (PPE) someone has to use at work when working with batteries.

The format of this work will look somewhat similar to the format of the second article that is reviewed in this paper titled, "Investigating Automotive Battery Explosions," by Charles Roberts. The reason it's going to follow a similar format is due to the fact that this article shows pictures to make a visual demonstration of what is being covered in the text. Figure-1 shows how a picture that gives a visual presentation of battery

related safeties when a battery exploded when a standby generator was starting during its regular maintenance. The top of the battery was blown away, suggesting that hydrogen was ignited inside the battery. The reasons for this is due to hydrogen gas is generated and accumulated in the head space above the electrolyte level during charging. Hydrogen gas has a wide range of explosion limits (4% to 70%) in the air. To have an ignition and cause of fire, fire triangle suggests that three elements need to be present which are fuel, oxygen, and ignition source. For this case, hydrogen is acting as fuel, air contains oxygen rich environment, and ignition source can be existing /initiating flame or spark. If the hydrogen is ignited inside the battery, then it typically blows off the top of the battery case, showing visible signs of sulfuric acid (H_2SO_4) in the immediate vicinity along with fragments of the battery case. Even though vents existed in that place, the vents could not relieve the pressure caused by the explosive energy generation as it was so rapid.

Figure 1: Two-year old battery that exploded, causing personal injury by acid burns [Roberts, 2013]

This kind of demonstrations is really helpful for the readers as they can see a real-world example of how a battery looks in the inside, how corrosion looks, and how fragments of a battery may look when they explode. By having visual representations more people are able to understand a concept better and will remain in their brains for longer periods of time since a picture is easier to remember than just multiple paragraphs of information.

METHODOLOGY

The primary methods that were used in this work were research on relevant articles and media creation. Effective research was highly important in this work because there was a need to find information on car batteries and their act of exploding. The information that needed to be researched on was the investigation techniques used in an explosion, the factors that may cause a battery explosion, and recommendations that can reduce the risk of a car battery exploding. The information that was gathered for the content of this work came from reliable sources that are either well known or specialized in investigations. The secondary method this work used was the techniques used in media creation in order to put all of the information and visual objects together in a way that is appealing and easy for the readers to comprehend. This method is just as important as the first method because even if quality of information is provided, if its not placed in a way that viewers can understand the effectiveness of this work would fail.

The analysis techniques that are used for this work are found from Jeffrey Oakley, 2012. There it is noted that an accident investigation is a structured process that is supposed to uncover causal factors and attempts to find corrective actions. It is also mentioned that an accident investigation needs to uncover and develop an accident sequence. With these things in mind the work covers finding corrective actions, as well as causal factors and techniques that investigators use in order to develop the accident sequence. Another analysis technique that is used in this work is change analysis. The reason this analysis technique is applicable to this work is because an accident investigation can start by comparing an accident-free sequence with a sequence that ended in an accident. For instance, we can compare a sequence that involves jump starting a car the right way and not having any problems to a sequence that involves connecting the cables to the battery the other/wrong way and having to deal with an explosion.

RESULTS AND DISCUSSIONS

After doing liturate reviews for this work, multiple causes of a battery explosion can be found. One of those causes is the ignition of hydrogen gas that is produced when a vehicle battery is being charged. Hydrogen produced during this activity may be ignited by a flame or a spark, which when there is enough of either one, it can end up in a bad situation. Other factors that may end up in an explosion while charging is overcharging and not charging the vehicle in ventilated area (Wong, 2009). Another cause of battery explosion is jump starting the vehicle which is mainly ignited by placing the jumper cables in an improper way. In addition, another common cause of a battery explosion is dirty post and cables that are most likely happened due corrosion. Dirt like corrosion may cause electrical resistance and act as an arc ignition source that may lead to a terminal being loose and not be secured properly (Roberts, 2013). Other causes of battery explosions are during checking or adding battery fluid, loose connections inside the battery, low electrolyte levels, and in some cases tools like screwdrivers been placed between the battery terminals.

It is also worth mentioning things that are inside a vehicle battery that can cause harm to humans. Obviusly the most harmful component that is inside a battery is the acid which is sulphuric acid (H_2SO_4) in vehicle batteries. Sulphuric acid is different from the acid that is found in the batteries that are used for household items e.g. alkaline batteries. Since vehicle batteries are bigger they need more acid to be able to operate correctly, the potential harm of this kind is more dangerous than the harm that can be caused by a household battery. Sulphuric acid can hurt skin, eyes, and lungs due to the fumes it may produce when it is about to explode or after an explosion. When someone gets contact with battery acid in his/her skin it is important for the person to create a solution of warm and soapy water to wash off the acid. If too much acid fell on the skin or made contact with the eyes, or was ingested or inhaled, it is better to get medical attention as soon as possible. Most of these cases do not get severe complications but it is important to take precautions anyways and seek appropriate medical help if needed (Massy, 2021).

A battery explosion investigation is a really hard thing to investigate since a lot of the evidence could be destroyed when it is not examined quick enough or is not found because it flew far from the scene. In addition, there is the possibility that the explosion happened when no one was around in that place or there was no security camera to have record of the instants before the explosion occurred. Therefore, it is possible that the only types of evidence available are physical and photographic by getting fragments of battery and taking pictures of where it happened (Roberts, 2013).

In one of the articles an example is given where there was an injury to an officer and the way they investigated this explosion was by examining the fragments, asking the officer what was going on and looking at what was left inside the vehicle. After the investigation they found out that the battery was spent the whole night charging, the battery was not being charged in a well-ventilated area, the officer was trying to refill the battery with fluid, that an iron tripod that fell into the battery was the spark of the explosion, and that the internal structure of the battery was fairly intact (Wong, 2009).

In the second article the investigation was mainly done by picking up and taking pictures of the fragments to examinate them and looking at the background story behind the accident. It was determined that the explosion was caused by hydrogen being ignited inside the battery and that is why the cap flew off. Therefore, physical and people evidence are highly important in this type of cases because the fragments can determine how the explosion was ignited and people can tell investigators what was going on before this happened.

Finally, in order to prevent any of these inconveniences there are some recommendations that

people can use in order to reduce the risk of an explosion. For instance, charging a battery needs to happen in a well-ventilated area and the battery being charged need to be monitored to prevent it from over charging. This means that the engine compartment is not the best place to charge the battery and should not be charged overnight because normally a battery finishes charging in around two hours. Another recommendation is that when a jump start is needed, it is best to connect the jumper cables to the dead battery first and then to the live battery and connect the negative cable on the dead battery to an unpainted metal portion of the frame to have sparks far from the battery (Vartabedian, 1999). Jump atarting also involves having both vehicles near, then turn off the vehicle, and unplugging accessories like phones and making sure the fluid inside the battery is liquid and not frozen when jump starting in cold weather (Firestone2016).

Another recommendation that will reduce the risk of sparks is to disconnect the negative terminal first and then remove the positive when removing a battery. During installing a battery connect the positive terminal first then the negative (AutoZone, 2017).

To continue with the recommendations, constant cleaning of the terminals and the cables can also reduce the risk of explosions. To do this there are chemicals that are safe to use to clean and prevent corrosion as well as adding some battery post grease in the posts, terminals, and cables to prevent this corrosion. In addition, never place tools in between the terminals as well as avoid smoking when the hood is up, and do not put to charge or try to fix a battery that is swollen. Another important recommendation when working with batteries is to wear safety goggles, an apron to protect your clothing, acid resistant gloves, and if possible a face shield.

Therefore, all of these simple recommendations are easy to follow and are highly effective in preventing damage to a car battery that may cause a catastrophic accident.

CONCLUSION

This work was able to identify multiple causal factors that may lead to a battery explosion, investigation methods used to determine the causal factors, and prevention measures people can take to prevent an explosion. Some of those causal factors include lack of maintenance of the cables and posts, not jump starting the vehicle accordingly, and improperly adding or checking battery fluid. In order to perform an investigation, a collection of battery fragments that leave over from the explosion need to be taken to the laboratory as soon as possible. There also need to have testimonies from people that might have seen the battery exploding or are victims of injuries caused by an explosion in order to see what is going on before the accident happened.

Prevention measures that can be used as recommend-ations include proper jump starting, proper removal and installation of the battery, charging the battery in the proper environment and avoid smoking or do anything that may cause a spark. Therefore, an accident investigation has the goal of determining the accident sequence and causal factors and is able to recommend preventative measures and the findings of this work cover all theses areas.

Works in the future can be more specific and have a large variety of information for each topic covered in this work. For instance, future works can find more causal factors and more recommendations for people to use and prevent more of these cases. Future works can also dig deeper into what is done in labs to the pieces that are left over from the explosions that occurred.

This work mentions that the fragments found are taken to labs and analyzed as soon as possible, however what is done inside the laboratories is not covered and future works can give readers this information. At the end, this work is detailed in all of the topics that it covered and has a variety of information, but there is a potential to be able to find even more information and be more detailed on some areas.

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